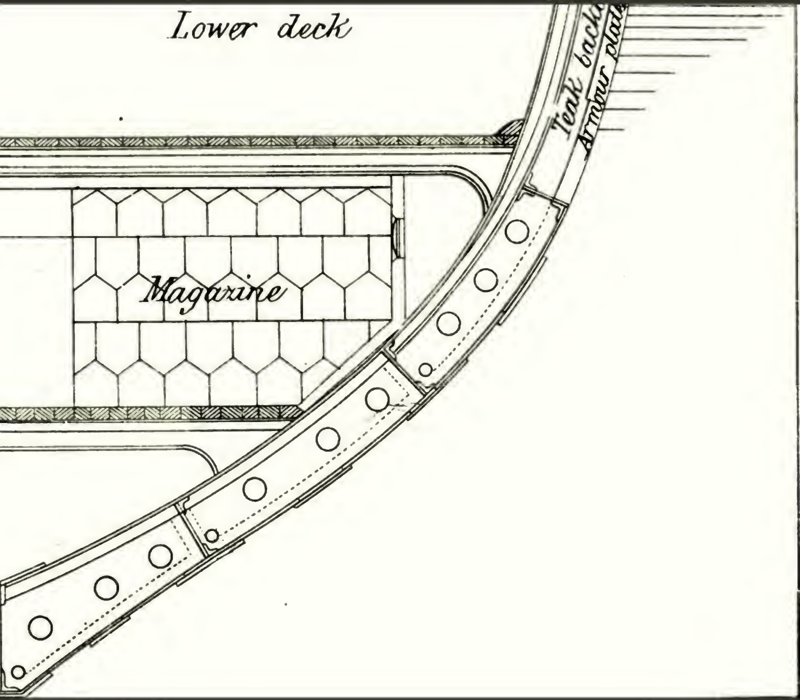

Papers on naval architecture, and other subjects connected ...

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PAPERS

ON

NAVAL ARCHITECTURE,

AND OTHER SUBJECTS CONNECTED WITH

NAVAL SCIENCE.

EDITED BY

WILLIAM MORGAN AND AUGUSTIN CREUZE,

NAVAL ARCHITECTS, FORMERLY STUDENTS AT THE SCHOOL OF NAVAL ARCHITECTURE IN HIS MAJESTY'S DOCK-YARD AT PORTSMOUTH.

No. XIII.—VOL. IV.

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CONTENTS

OF

No. XIII.

Page

ART. I. Chapman's Work on Ships of War, translated from the Swedish. By WM. MORGAN, of His Majesty's Dock-yard at Sheerness; Member of the School of Naval Architecture. —(Continued from page 388 of Vol. III.) - 1

II. On Rotatory and Rectilinear Motions; with Observations on the Effects of those Forces which are, in some cases, brought into operation by them. By MR. LLOYD, of His Majesty's Dock-yard, Portsmouth, formerly of the School of Naval Architecture - - 36

III. Observations relative to the late experimental Cruises of Ships of War, with a view of showing by what means a future experimental Trial of Ships may be rendered subservient to the advancement of the Science of Naval Architecture. By MR. WILLIAM HENWOOD, of His Majesty's Dock-yard, Portsmouth; Member of the School of Naval Architecture - - - - - 49

Page

ART. IV. Notice of a Pamphlet "On the Advantages of observing a Ship's Inclination at Sea, &c., by Henry Chatfield, of His Majesty's Dock-yard at Plymouth, Member of the School of Naval Architecture" - - - - - 60

V. Notice of "Scales of the Displacements; and of the Areas of the Horizontal and Vertical Sections; and of the Areas of the external Surface of the several Classes of Ships composing the British Navy, &c., by William Parsons, of His Majesty's Dock-yard, Portsmouth, Naval Architect, formerly a Student of the School of Naval Architecture" - 66

VI. A new Method of constructing Beds and Coins for Naval Guns. By Mr. HENRY CHATFIELD, of His Majesty's Dock-yard, Plymouth; Member of the School of Naval Architecture - - - - - - - 80

VII. On the Protection of Ships from Lightning. By W. SNOW HARRIS, Esquire, F.R.S.—(Continued from page 446 of vol. III.) - 93

VIII. A List of Patents which have been taken out since the 1st of July, 1831, for Inventions or Improvements connected with Naval Affairs; with Extracts from Specifications, &c. - - - - - - - - 108

ADVERTISEMENT.

The Editors having observed the want of a scientific publication on this important National and Commercial subject, have been induced to revive the "*Papers on Naval Architecture.*" They feel they cannot do better, as illustrating their views, than to reproduce the Advertisement of Messrs. Morgan and Creuze, which accompanied the First Volume of these Papers in 1826:—

> "The state of the science of Naval Architecture is very imperfectly known in this country, arising not more from the difficulty of the subject than from the smallness of the number, and the character of the works, published on it. The abstruse manner in which it is necessary to treat many parts of the theory, and the wholly practical manner in which the construction of a ship is generally treated, render these works far better adapted for the student than for the general reader.
>
> "It is proposed, in this work, by a combination of popular and scientific papers, to give a general view of the theory and practice of Naval Architecture. The increasing interest this subject has lately excited appears to render such a work desirable.
>
> "All pretensions to the discovery of secrets in Naval Architecture will be disclaimed, as altogether inconsistent with the nature of the subject. The means of improvement in this science are the collection of facts, experiment, mathematical reasoning, and general observation; and success is to be expected only in proportion to the talent and labour devoted to it. The extent and difficulty of the subject render a very rapid advancement improbable; but there is nothing in its character which can be shown to prevent the general mode of philosophical investigation being equally applicable to this as to other sciences; and it is reasonably to be expected, that, by equal attention to it, it will advance certainly, though slowly, to the same degree of excellency. While the conductors of this work believe mathematics to be so closely connected with its improvement, that many of its branches cannot be understood without it, they yet consider that the judicious opinion of experienced men, however unconnected with scientific reasoning, is to be received with the greatest respect, as tending to enlarge our knowledge, and direct future investigation in this science.

"It will be the object of this work to collect all the information that can be obtained on Naval Architecture, and other subjects connected with Naval Science. It will relate particularly to the Design of our Ships, their Construction, the Nature of the Materials of which they are built, and the Direction of them at sea. The matter of this work will be composed of Original Papers, Translations, and Extracts from works on Naval Science, Critical Remarks, and Correspondence.

"It is considered that, by having a work wholly devoted to this subject, much useful matter will be obtained, which would otherwise remain unpublished; particularly, it is hoped, the observations of naval officers, by a combination of whose valuable experience with the theoretical knowledge of the naval architect, much advantage to this science may be expected."

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Part No. XIV., Vol. IV. (New Series, Monthly), will be published on the 1st November, 1865, and on the 1st of each succeeding Month.

London, 1865.

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* The reprint of Part XIII., commencing Vol. IV., will be supplied to Subscribers at the same price as the New Series; to Non-subscribers at 5s.

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PAPERS

ON

NAVAL ARCHITECTURE,

&c.

ARTICLE I.—*Chapman's Work on Ships of War, translated from the Swedish, by* WM. MORGAN, *of his Majesty's Dockyard at Sheerness.*—(Continued from page 388, vol. 3.)

CHAP. XVI.

51. THE parabolic method of construction will be now applied to the construction of frigates, as it has been to ships of the line; namely, of a frigate of 40 guns, one of 32, and another of 20 guns, also of a brig of 8 guns. The determination of the displacements will be found further forward in this work, where general rules are given for a greater number of frigates, according to the parabolic method of construction. Likewise a frigate of 52 guns will be inserted first in the Tables, formed according to the same method. The most important elements which are necessary in the construction of these vessels are found in the following Table. For the proportions of the frigate of 52 guns, which are marked *, the rules inserted have not been used.

TABLE No. 39.

	52	40	32	20	8
Displacement $= D$	66753*	46877	30434	20162	3821
Length of the water-line of construction $= 4{,}1809 \,.\, D^{\frac{1}{3}} = l$	166,00*	150,75	130,53	113,80	65,38
Increase forward $= 1{,}75$, and abaft $= 1{,}0$, $= f$	2,75	2,75	2,75	2,75	2,75
$l + f = L$	168,75	153,50	133,28	116,55	68,13
Breadth at the water-line $\frac{l^{0,8057}}{1{,}4063} = B$	45,00*	40,46	36,02	32,25	20,64
Depth of the ⊕ section to the keel $= 0{,}1023.\ L =$	17,60*	15,70	13,63	11,92	6,97
$1{,}6491 \,.\, D^{0,0293} = n$	2,33*	2,26	2,232	2,205	2,1
Depth of the line of sections at the ⊕ section $= \frac{\overline{n+1} \,.\, D}{n\, l\, B} = \mathrm{h}$	12,771	11,087	9,373	7,985	4,183
Area of the ⊕ section $= \mathrm{h} \,.\, B =$ ⊕	574,71	448,55	337,62	257,52	86,34
Centre of gravity before the middle of $L = \frac{L}{80}$	2,11	1,919	1,666	1,457	0,852
Centre of gravity before the middle of $l = \mathrm{a}$	2,485	2,294	2,041	1,832	1,227
⊕ section before the middle of the water-line of construction $l = \mathrm{a} \,.\, \overline{n+2}$	10,76	9,772	8,64	7,770	5,03
Depth of ⊕ section of construction $= \frac{D^{0,3417}}{2{,}63} = d$	16,93	15,00	12,94	11,24	6,37
From the ⊕ section to the fore-end of l	72,24	65,60	56,62	49,20	27,66
From the ⊕ section to the after-end of l	93,76	85,15	73,91	64,60	37,72
Height of battery	6,33	8,33	7,25	6,33	4,00

TABLE No. 40.

Calculations of the ordinates h of the line of sections (according to the equation $x = \frac{y^n}{p}$*), and thence the areas of the sections and the ordinates C of the ribband-line.*

Double Frigate of 52 guns.					
Ordinate y	$\frac{y^{2,33}}{16,74} = x$	Ordinates of line of sections $\mathrm{h} - x = h$	Half areas of sections $\frac{1}{2} B . h = 22,5 . h$	Ordinates C of ribband-line.	
				Forward.	Abaft.
10	12,771	0,000	0,00	—	—
9	9,991	2,780	62,55	4,90	4,29
8	7,593	5,178	116,50	7,15	6,58
7	5,563	7,208	162,18	8,80	8,34
6	3,885	8,886	199,94	10,07	9,72
5	2,540	10,231	230,20	11,03	10,80
4	1,510	11,261	253,37	11,75	11,61
3	0,773	11,998	269,34	12,25	12,18
2	0,300	12,471	280,60	12,57	12,54
1	0,060	12,711	286,00	12,73	12,72
⊕	0,000	12,771	287,36	12,771	12,771
Forward $C = 0,333\,h + 0,667\,\sqrt{\mathrm{h}\,h}$			Abaft $C = 0,525\,h + 0,475\,\sqrt{\mathrm{h}\,h}$		

Frigate of 40 guns.					
Ordinate y	$\frac{y^{2,26}}{16,414} = x$	Ordinates of line of sections $\mathrm{h} - x = h$	Half areas of sections $\frac{1}{2} B . h = 20,23\,h$	Ordinates C of ribband-line.	
				Forward.	Abaft.
10	11,086	0,000	0,00	0,00	0,00
9	8,737	2,349	47,54	4,28	3,66
8	6,695	4,391	88,84	6,21	5,62
7	4,951	6,135	124,12	7,62	7,14
6	3,495	7,591	153,58	8,70	8,34
5	2,315	8,771	177,45	9,54	9,29
4	1,398	9,688	196,00	10,16	10,01
3	0,730	10,356	209,51	10,61	10,53
2	0,292	10,794	218,37	10,90	10,86
1	0,061	11,025	223,05	—	—
⊕	0,000	11,086	224,27	10,086	11,086
For this and the following at the 7th section .... $\begin{cases} C = 1,3406 \,.\, h^{0,958} \text{ forward} \\ C = 1,2401 \quad h^{0,965} \text{ abaft} \end{cases}$					
Forward $C = 0,297\,h + 0,703\,\sqrt{\mathrm{h}\,h}$			Abaft $C = 0,524\,h + 0,476\,\sqrt{\mathrm{h}\,h}$		

TABLE No. 40.—(*continued.*)

Frigate of 32 guns.						Frigate of 20 guns.					
Ordinate y	$\frac{y^{2'232}}{18,202} = x$	Ordinates of line of sections $\mathrm{h} - x = h$	Half areas of sections $\frac{1}{2} B . h = 18,01 . h$	Ordinates C of ribband-line.		Ordinate y	$\frac{y^{2'205}}{20,078} = x$	Ordinates of line of sections $\mathrm{h} - x = h$	Half areas of sections $\frac{1}{2} B . h = 16,125\ h$	Ordinates C of ribband-line.	
				Forward.	Abaft.					Forward.	Abaft.
10	9,373	0,000	0,00	0,00	0,00	10	7,985	0,000	0,00	0,00	0,00
9	7,409	1,964	35,37	3,64	3,10	9	6,330	1,655	26,69	3,11	2,65
8	5,696	3,677	66,22	5,25	4,75	8	4,882	3,103	50,04	4,48	4,04
7	4,228	5,145	92,66	6,44	6,02	7	3,637	4,348	70,11	5,48	5,12
6	2,997	6,376	114,83	7,35	7,04	6	2,589	5,396	87,01	6,25	5,98
5	1,995	7,378	132,88	8,05	7,84	5	1,736	6,249	100,77	6,85	6,66
4	1,213	8,160	146,96	8,58	8,45	4	1,059	6,926	111,68	7,30	7,18
3	0,638	8,735	157,32	8,96	8,89	3	0,561	7,424	119,71	7,63	7,56
2	0,258	9,115	164,16	9,21	9,18	2	0,230	7,755	125,05	7,84	7,81
1	0,055	9,318	167,82	9,34	9,33	1	0,050	7,935	127,95	7,95	7,95
⊕	0,000	9,373	168,81	9,37	9,37	⊕	0,000	7,985	128,76	7,985	7,985
Forward			Abaft			Forward			Abaft		
$C = 0,2807 . h + 0,7193 \sqrt{\mathrm{h}\, h}$			$C = 0,5109 . h + 0,4891 \sqrt{\mathrm{h}\, h}$			$C = 0,267 . h + 0,731 \sqrt{\mathrm{h}\, h}$			$C = 0,499 . h + 0,501 \sqrt{\mathrm{h}\, h}$		

TABLE No. 40.—(*continued.*)

Brig of 8 guns.					
Ordinate y	$\frac{y^{2,1}}{30,096} = x$	Ordinates of line of sections $\mathrm{h} - x = h$	Half areas of sections $\frac{1}{2} B . h = 10,32 . h$	Ordinates C of ribband-line. Forward.	Ordinates C of ribband-line. Abaft.
10	4,183	0,000	0,00	0,00	0,00
9	3,353	0,830	8,57	1,64	1,40
8	2,618	1,510	15,58	2,30	2,06
7	1,978	2,205	22,76	2,86	2,66
6	—	—	—	—	—
5	0,976	3,207	33,10	3,56	3,46
4	—	—	—	—	—
3	0,334	3,849	39,72	3,98	3,94
2	—	—	—	—	—
1	—	—	—	—	—
⊕	0,000	4,183	43,17	4,183	4,183
Forward $C = 0,213 . h + 0,787 \sqrt{\mathrm{h}\, h}$			Abaft $C = 0,453 . h + 0,547 \sqrt{\mathrm{h}. h}$		

The drawings which are constructed according to these calculations are found in plates XX, XXI, XXII, XXIII, and XXIV. Each frigate has two plates with the same number. The sheer-draughts are marked *A*, and the body-plans *B*.

The measurements are then taken from these drawings, and their results inserted in the following Table.

TABLE No. 41.

	52	40	32	20	8
Displacement $= D$	66788	46862	30498	20221	3817
Centre of gravity before middle of water-line of construction l	2,451	2,254	2,053	1,815	1,258
Ditto before middle of water-line L	2,076	1,869	1,678	1,440	0,883
Half area of upper water section $= W$..	3196	2582	1988	1536	539,4
$\frac{\int \frac{2}{3} y^3 \, d x}{D} = p$	13,54	12,454	11,639	10,767	7,868
Centre of gravity of displacement below upper water-line $= g$	6,22	5,459	4,66	4,022	2,263
Metacentre above water-line $p - g = e$	7,32	6,995	6,979	6,745	5,605

52. From the calculations of the effect of the water in opposing the motion of the two frigates of 40 guns, the one constructed by the relaxation-line and the other by the parabolic method, it is found, that on the former the resistance of the water forward is = 2459,7, and the force of cohesion abaft is = 345,49, the sum of which is = 2805,19; and on the latter the resistance of the water forward is = 2405, and the force of cohesion abaft is = 470,92, the sum of which is = 2875,92. Consequently, if the little difference of the resistances on the bows of these two ships is neglected, so that they may be considered equal, then the excess arising from the inequality of the force of cohesion abaft, is on the whole not more by the parabolic method, than about one-twentieth part of the greater resistance.

That the application of the relaxation-line does not conduce more to fast sailing, may be inferred, it appears, from what follows.

With a new frigate of 40 guns, in which the relaxation-line was so applied that it should produce the greatest effect possible in diminishing the force of the cohesion of the water abaft, an experimental cruise was made last summer, 1803, under my inspection, in the Baltic; and I let some trials be made, in an ordinary and steady topsail breeze and in smooth water close-hauled, but not nearer to the wind than from 7 to 6½ points, and sailing at about 9 knots; I gave the frigate a greater or less difference of draught of water, by a certain quantity of pig-ballast, which was placed for the occasion in midships on the orlop deck. It was found by a constant use of the log-line, that its velocity was something greater, when it sailed at the water-line drawn on the draught, than when it had more or less difference of draught of water, which confirms the truth of the theory; but when tried in a high sea there was no difference in the velocity. It should likewise be remarked, that this frigate was not coppered, which certainly increased the difference; but in all cases it should be concluded, that the form which is produced by the application of the relaxation-line, in respect to fast sailing, is of little consequence, and that its application to the construction of ships muy be omitted; but the method of calculating the effect of the water in opposing the course of a ship, will, nevertheless, in all respects remain the same, and more especially, as it cannot be omitted in the formation of a ship of the line.*

53. The frigates inserted in the foregoing section 51, are given as examples of construction by the parabolic method; but as there are many different services for which frigates are required, a considerable number are inserted in the following table, some of which it is presumed will be found there adapted to the purpose; but if vessels of any other kind of armament, &c., than are given in this table, are required, all their proportions can be obtained from the given expressions; and the same method of construction can be used for all ships and vessels, of any magnitude and intended for any purpose. A parallelopiped will in the first place be formed, for these vessels as for ships of the line, from the displacement, and thence the parabolic element; the rest follows in the same order.

---

* What is observed about the middle of the 8th section on the resistance of the water on bodies, in the "Transactions of the Royal Academy of Sciences," must not be neglected to be remarked, namely, "That the water on the windward side of the after part of a ship, has a considerable effect in bringing a ship up to the wind, &c.," which was experienced in the ardency of the just-mentioned frigate of 40 guns, which arises partly from the diminution of the force of cohesion.

TABLE No. 42.

Frigates and smaller armed Vessels.

	44		40	
	No.	Pounder.	No.	Pounder.
Guns on deck	26	30	26	24
Guns on quarter-deck and forecastle	18	12	14	8
Crew $= m$	400		330	
Number of months for which provisioned $= M$	5		5	
Guns, &c., and ammunition for 60 rounds per gun in cubic feet of water	6275		4819	
Weight of crew with their effects, at 4 cubic feet each	1600		1320	
Provisions and tare; wood for a month; water and tare for half that time, at 4,767 cubic feet per man $= 4{,}767 \,.\, m.\, M =$	9534		7865	
Ballast	5650		4649	
Total $= S$	23059		18653	
Weight of vessel itself $= 1{,}2265.\ S$	28282		22878	
Mast and yards, boats, galley, cordage and rigging, sails, anchors, cables and hawsers, blocks, dead-eyes, master's and carpenter's stores, &c. $= 1{,}0192.\ S^{0,871}$	6431		5346	
Total displacement $= D$	57772		46877	
Length of the water-line of construction $= 4{,}1809\ D^{\frac{1}{3}} = l$	161,63		150,75	
Increase forward $= 1{,}75$; abaft $= 1{,}0 = f$	2,75		2,75	
Whole length of water-line between rabbets $= l + f = L$	164,38		153,50	
Greatest breadth at the water-line $= \frac{l_{0,7884}}{1{,}2892} = B$	42,74		40,46	
Depth of the parallelopiped $\frac{D}{l\,B} = t$	8,3630		7,6856	

TABLE NO. 42.—(*continued.*)

	36	32	28	24	20	16	14	12	10	8
	No. Pdr.	No. Pdr.	No. Pdr.	No. Pdr.	No. Pdr.	No. Pdr.	No. Pdr.	No. Pdr.	No. Pdr.	No. Pdr.
Guns on deck	24 18	24 12	22 12	20 12	20 12, l.w.	16 8	14 6	12 6, l.w.	10 4	8 4, l.w.
Guns on quarter-deck and forecastle	12 6	8 6, l.w.	6 4	4 4, l.w.	—	—	—	—	—	—
m	278	238	213	194	179	149	115	86	52	32
Number of months, &c. M	5	5	$4\frac{3}{4}$	$4\frac{1}{2}$	$4\frac{1}{3}$	4	4	4	4	4
Guns, &c.	3351	2325	1997	1756	1473	923	611	433	285	196
Weight of crew, &c.	1112	952	852	776	716	596	460	344	208	128
Provisions and tare, &c. $4,767 . m M$	6626	5672	4822	4162	3697	2841	2192	1640	991	610
Ballast	3756	3081	2492	2258	2031	1548	1210	944	750	523
S	14845	12030	10163	8952	7917	5908	4473	3361	2234	1457
$1,2265 . S$	18207	14755	12465	10980	9710	7246	5486	4122	2740	1787
Masts and yards, &c. $= 1,0192 . S^{0{\cdot}871}$	4382	3649	3150	2821	2535	1964	1541	1202	842	580
D	37434	30434	25778	22753	20162	15118	11500	8685	5816	3824
$l.$	139,86	130,53	123,51	118,47	113,79	103,38	94,37	85,94	75,19	65,38
f	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75	2,75
L	142,61	133,28	126,26	121,22	116,54	106,13	97,12	88,69	77,94	68,13
B	38,14	36,12	34,58	33,46	32,413	30,05	27,97	25,98	23,38	20,94
t	7,0177	6,4551	6,0356	5,7399	5,4670	4,8665	4,3568	3,8899	3,3084	2,7932

TABLE No. 42.—(*continued.*)

	44	40
Abscissa of the line of sections, or its depth at $\oplus$ section $= 1{,}51144\,.\,t^{0{,}977} = \mathrm{h}$	12,040	11,0862
Exponent of the line of sections $= \frac{t}{\mathrm{h} - t} = n$	2,2744	2,2600
Area of $\oplus$ section $= B\,.\,\mathrm{h} = \oplus$	514,60	448,55
Depth of $\oplus$ section of construction $= 1{,}8041\ \mathrm{h}^{0{,}8804} = d$........	16,130	15,000
Depth of $\oplus$ section to upper side of rabbet of keel $= 1{,}2018\,.\,d^{0{,}949} = q$	16,82	15,70
Exponent of $\oplus$ section $= \frac{\oplus}{B\,d - \oplus} = m$........	2,9439	2,8327
Half area of water-line $= \frac{\overline{\frac{1}{2} B\,L)}^{1{,}0553}}{1{,}8761} = W$	2940,8	2582,0
Exponent of water-line $= \frac{W}{\frac{1}{2} B\,L - W} = r$	5,1413	4,9341
Moment $\frac{\overline{\overline{\frac{1}{2} B)}^{2}.\,W)}^{1{,}019}}{2{,}3564} = \int \frac{2}{3}\,y^3\,d\,x$	745176	583650
From centre of gravity of displacement to metacentre $= \frac{\int \frac{2}{3}\,y^3\,d\,x}{D} = p$	12,899	12,450
Exponent of displacement, calculated from the water-line downwards $\frac{\frac{1}{2}\,D}{d\,W - \frac{1}{2}\,D} = s$........	1,5573	1,5327
Centre of gravity of displacement below water-line $= \frac{\overline{s+1}\,.\,\overline{2\,s+1} + s\,.\,\overline{2\,s+4}\,.\,d}{2\,.\,\overline{2\,s+1}\,.\,\overline{2\,s+4}} = g$	5,9514	5,5159
Metacentre above water-line $= p - g = e$........	6,948	6,934
Common centre of gravity of ship above water-line $= v$	2,400	2,300
Distance between the metacentre and this centre of gravity $= a$	4,548	4,634
It is assumed that the centre of gravity shall be before the middle of water-line $L = \frac{L}{80}$........	2,055	1,919
Middle of water-line l abaft the middle of water-line L	0,375	0,375
Centre of gravity before the middle of water-line of construction $l = \mathrm{a}$	2,430	2,294
Situation of $\oplus$ section before centre of gravity $= \mathrm{a}.\,\overline{n+1}$........	7,957	7,478
Situation of $\oplus$ section before middle of water-line of construction $l = \mathrm{a}.\,\overline{n+2}$	10,387	7,772

TABLE No. 42.—(*continued.*)

	36	32	28	24	20	16	14	12	10	8
h	10,144	9,3486	8,7545	8,3352	7,9478	7,0937	6,3669	5,6993	4,8653	4,1236
n	2,2447	2,2309	2,2199	2,2116	2,2037	2,1850	2,1675	2,1498	2,1250	2,1000
⊕	386,89	337,67	302,73	278,90	257,59	213,17	178,08	148,07	113,75	86,35
d	13,872	12,909	12,184	11,669	11,190	10,125	9,2053	8,3500	7,2643	6,28
q	14,58	13,62	12,89	12,37	11,89	10,81	9,88	9,00	7,89	6,87
m	2,7209	2,6257	2,5528	2,5004	2,4514	2,3402	2,2431	2,1503	2,0280	1,9125
W	2244,8	1973,4	1780,1	1647,0	1527,7	1277,9	1078,9	906,83	707,92	546,8
r	4,7279	4,5512	4,4182	4,3228	4,2342	4,0350	3,8629	3,6973	3,4839	3,2841
$\int \frac{2}{3} y^3 \, dx$	456060	352180	290120	250640	217550	155460	113040	81471	51061	31351
p	12,183	11,572	11,255	11,016	10,790	10,283	9,8293	9,3807	8,7794	8,2000
s	1,5066	1,4834	1,4647	1,4505	1,4373	1,4050	1,3751	1,3446	1,3014	1,2563
g	5,0827	4,7145	4,4378	4,2412	4,0120	3,6547	3,3071	2,9850	2,5780	2,2109
e	7,100	6,858	6,817	6,775	6,778	6,628	6,522	6,396	6,201	5,989
v	2,134	1,991	1,884	1,807	1,736	1,577	1,440	1,311	1,147	0,997
a	4,966	4,867	4,933	4,968	5,042	5,051	5,082	5,085	5,054	4,992
$\frac{L}{80}$	1,783	1,666	1,578	1,515	1,457	1,327	1,218	1,109	0,974	0,852
Middle of, &c.	0,375	0,375	0,375	0,375	0,375	0,375	0,375	0,375	0,375	0,375
a	2,158	2,041	1,953	1,890	1,832	1,702	1,593	1,484	1,349	1,227
a. $\overline{n+1}$	7,002	6,591	6,288	6,070	5,869	5,421	5,046	4,674	4,216	3,804
a. $\overline{n+2}$	9,160	8,631	8,241	7,960	7,701	7,123	6,639	6,158	5,565	5,031

TABLE NO. 42.—(*continued.*)

	44	40
From middle of water-line L to $\oplus = k$	10,01	9,40
Greater draught of water abaft than forward $= \frac{L^{0 \cdot 653}}{15,744} = c$	1,78	1,70
Depths from the water-line L to the upper side of the keel forward and abaft. The sign + belongs to the after-depth, and the sign − to the foremost $= q \pm \overline{\frac{e}{2} \pm \frac{ck}{L}}$ abaft	17,81	16,65
forward	16,03	14,95
$\frac{l}{2}$	80,815	75,375
From the after-end of l to the $\oplus$ section =	91,202	85,147
Distance between the sections abaft, $\frac{1}{10}$ part of the above distance =	9,120	8,515
From the foremost end of l to the $\oplus$ section =	70,428	65,603
Distance between the sections forward, $\frac{1}{10}$ part of the above distance =	7,043	6.560
Height of battery above the water	8.67	8,33
Displacement to the outside of the planking $= \frac{20}{19} D = Q$	60813	49346
Moment of the ship's stability $= a\ Q$	276580	228670
Weight of the men at the guns and small-arms $= P$	626	513
Their centre of gravity from midships $= b$	14,0	13,4
Moment of these men in action $= b\ P$	8764	6874
(1) Moment of the power of the sails $= M$	25007	21045
59,56. $M = W$	1489400	1253400
From upper side of gun-deck to topmast fid $= B\ C$	5,50	5,13
From centre of gravity to topmast fid $= d$	10,27	9,70
Breadth of the lower edge of the maintopsail (2) $= x$	80,89	76,37

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(1) See "the area of sails for ships of the line, § 12 and 13."

(2) The proportions of the sails of the fore and mizen masts are the same as for those of ships of the line. The form of the stem being a conic parabola, &c., may be seen on the draughts.

TABLE No. 42.—(*continued.*)

	36	32	28	24	20	16	14	12	10	8
k	8,79	8,26	7,87	7,59	7,33	6,75	6,26	5,78	5,19	4,66
c	1,62	1,55	1,50	1,46	1,42	1,34	1,26	1,19	1,09	1,00
$q \pm \overline{\frac{c}{2} \pm \frac{c\,k}{L}}$ abaft	15,49	14,49	13,73	13,19	12,69	11,57	10,59	9,67	8,51	7,44
forward	13,87	12,94	12,23	11,73	11,27	10,23	9,33	8,49	7,43	6,44
$\frac{l}{2}$	69,93	65,265	61,755	59,235	56,895	51,690	47,185	42,97	37,595	32,600
From the after, &c.	79,090	73,896	69,996	67,195	64,596	58,813	53,824	49,128	43,160	37,631
Distance between, &c.	7,909	7,390	7,000	6,720	6,460	5,881	5,382	4,913	4,316	3,763
From the foremost, &c.	60,77	56,634	53,514	51,275	49,194	44,567	40,567	36,812	32,030	27,569
Distance between, &c.	6,077	5,663	5,351	5,128	4,919	4,457	4,057	3,681	3,203	2,757
Height of battery, &c.	7,75	7,25	7,00	6,67	6,33	5,83	5,33	5,00	4,50	4,00
Q	39404	32036	27135	23951	21171	15914	12105	9142	6122	4025
$a\,Q$	195680	155920	133860	118990	106744	80382	61517	46487	30940	20093
P	432	351	291	248	221	183	121	108	70	54
b	12,7	12,1	11,6	11,2	10,8	10,0	9,4	8,8	8,0	7,0
$b\,P$	5486	4247	3376	2778	2387	1830	1137	950	562	378
(1) M	18402	14787	12993	11744	10640	7980	6369	4524	3213	2074
W	1096030	880710	773860	699470	633720	475290	379340	—	—	—
$B\,C$	4,76	4,44	4,20	4,03	3,87	3,51	3,21	3,00	2,65	2,37
d	8,97	8,35	7,99	7,56	7,13	6,54	6,00	5,58	5,00	4,37
x	73,14	68,02	65,11	63,01	61,03	55,43	51,43	—	—	—

In case it is required that either of these vessels shall have a greater area of sails; then a, the distance between the centre of gravity and the metacentre is greater, and consequently the distance p is so much the greater; and put the new value $p = p'$. To find, therefore, the new breadth, a different expression from that in the table must be given for finding the moment of stability $\int \frac{2}{3} y^3 \, d\, x$, which is the same as for ships of the line, but adapted to frigates; namely, $\int \frac{2}{3} y^3 \, d\, x =$

$$\frac{\overline{\tfrac{1}{2} B^3 . L}^{\,1,04895}}{4,3325} = p' D,$$ hence the new half breadth $\frac{1}{2} B' =$

$$\sqrt[3]{\frac{4,3325\, p' D_{\frac{1}{1,04895}}}{L}}.$$

The situation of the centre of gravity appears thus to be much higher above the water-line in frigates than in ships of the line, which arises not only from the weight of the masts, yards, and rigging, being greater in relation to the displacement in frigates than in ships of the line, but also from frigates being sharper in the bottom.

As it is not necessary to be so particular as to the depth of smaller vessels; and as these vessels, on account of their light weight, possess little power to continue their way when they luff up to come to the wind; and as it is especially necessary that in coming about they should have as much way as possible, which takes place when the centre of gravity is in or near the middle of the length of the water-line of the vessel; and as both ends are equally full, a considerable difference of draught of water abaft must be given, by which the after-displacement is increased below, and is correspondingly decreased at the water-line, by which the stability is somewhat diminished, which can however be compensated by an increase of breadth in midships; which always determines itself in the construction of the drawings. The centre of effort of the sails should then come further aft, which also conduces to the vessel's readiness in coming about.

It is seen, as well from this Table as from Table No. 33, that although ships of the line, as well as frigates, are formed by rules founded on the same principle, they nevertheless vary much in respect to their form.—Compare, for instance, the ⊕ section of the ship of 110 guns with that of the brig of 8 guns, and it will be found from their exponents that there is no similarity between them; when, therefore, the length, breadth, and depth of a ship are given, and the displacement within these limits, safe and constant rules can be formed, by which the drawings can be constructed.

A constant method of constructing the drawings is thus obtained, which is denominated the PARABOLIC METHOD OF CONSTRUCTION, (see § 40,) which is applicable to all sorts of ships and vessels, of every armament and for every purpose without exception; and will be found as indispensable to a person forming a ship's drawings, as logarithms are to a mathematician.

APPENDIX.

ON GUNS AND TRAVERSE CARRIAGES.

On Guns.

It may be inferred from what has been said, that a ship of war is to be regarded solely in relation to its guns; a description and general drawing of guns will be here given, such as they should be for the armament of ships, agreeably to the calibre measure adopted in Sweden.

Fig. 1 is a general drawing of all the guns commonly used in Sweden; namely, 48, 42, 36, 30, 24, 18, 12, 6, and 4-pounders: nine kinds. All of them are constructed by the same scale of calibre. The same principle on which this construction is founded was adopted by me some years ago, and is given in the new "Transactions of the Royal Academy of Sciences," vol. 23, for the year 1802; in the first quarter of which is inserted, *A Theoretical Treatise, founded on experiment, to give the proper form of guns, that their strength at all parts may be proportionate to the expansive force of gunpowder, see Fig.* 3 *and* 5*;* and what was inserted in § 21 concerning the guns used at sea is to be observed.

b b is the bore of the gun, *b a a b* is the chamber for the powder, which is one-fifth smaller at the bottom *a a* than at the fore-part of the powder *b b*. The ticked line *d e f h k n*, which is the line of construction of the gun, is an hyperbola, within which line the external surface of the gun does not pass at any place before *e*.

If the gun were of a parallel bore to the bottom of the chamber, its external form at the after-part over the chamber would be *o d e*, if its strength were proportional to the expansive force of the powder; but as the gun would then be of an improper shape, and also of too great a weight, it has been found necessary to diminish the width of the bore at the bottom of the chamber, as *a a*, and consequently its exterior diameter is diminished, so that it becomes *t u*, by which a considerable diminution is obtained in its weight, though it is nevertheless quite as strong as when the bore is parallel, and the exterior surface is *o d e*.

There is conclusive evidence that guns of this construction do not burst.

Between *f* and *g* the second reinforce moulding is terminated for all the nine sorts of guns, between *h* and *i* the first reinforce moulding is terminated, between *k* and *l* is the fore-part of the muzzle ring, and between *m* and *n* is the muzzle. The diameter of the gun at *e*, the foremost end of the powder chamber, is in a constant proportion to the calibre for all the guns. In other respects the manner of constructing the guns may be found from the drawing. All the measurements are made by the scale of calibre placed near it, and all the calibres, &c., are inserted in the following Table. The lower half of the figure represents a 36-pounder. Between *p* and *q* is the centre of the trunnion, and between *r* and *s* is the centre of gravity of each gun.

	48	42	36	30	24	18	12	6	4
Diameter of calibre, in feet	0,6586	0,6299	0,5984	0,5631	0,5228	0,475	0,4149	0,3292	0,2877
Length of bore, in feet	10,000	9,658	9,275	8,841	8,338	7,731	6,950	5,793	5,208
Length of bore, in calibres	15,2	15,833	15,5	15,7	15,949	16,276	16,751	17,597	18,102
Weight of gun, in skipponds light weight	30,986	27,230	23,454	19,660	15,840	11,990	8,097	4,139	2,795
Trunnion and trunnion plate in light weight	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1	0,066
Total weight of gun, in skipponds light weight	31,786	27,930	24,054	20,160	16,240	12,290	8,297	4,239	2,861
Coins in lb. provision weight	33,86	29,95	26,56	23,04	19,36	15,52	11,26	6,56	4,67
From cascabel to centre of gravity, in calibres	7,825	7,864	7,913	7,971	8,043	8,141	8,276	8,520	8,665
Between centre of gravity and centre of trunnion, in calibres	0,574	0,581	0,603	0,630	0,665	0,717	0,788	0,937	1,038
Weight of shot in lb. provision weight	59,80	52,28	44,81	37,34	29,81	22,34	14,87	7,44	4,95
Number of shot = weight of gun	170	171	72	173	174	176	178	182	185
From centre of trunnion to muzzle, in feet	6,463	6,236	5,980	5,695	5,364	4,957	4,441	3,674	3,284
Length of trunnion beyond trunnion plate, in calibres	0,840	0,840	0,840	0,840	0,840	0,841	0,843	0,850	0,869
Length of gun from outer end of cascabel to muzzle, in feet	12,157	11,721	11,235	10,685	10,050	9,287	8,309	6,871	6,150
Weight of a charge of powder, in lb.	16,00	14,32	12,60	10,83	9,00	7,09	5,06	2,85	2,03

On the Traverse Carriage.

As the lower-deck guns, on account of their weight and their being more easily worked, should be placed on traverse carriages: an improved traverse carriage is drawn on the same plate, in which the sand and dirt cannot cause any impediment. See *Kannedom af Linie skepp,* note to § 4.

Fig. 2 is a 36-pounder, standing in board on its carriage, lying on the slide in the traverse. It can be elevated 8¾ degrees, and depressed 4½, making together 13¼ degrees. At the midship port it can be trained forward 17½ degrees, and as much abaft, making together 35 degrees.

A is the upper side of the traverse, *B* is the upper side of the slide, *C* its lower side, *D* is the upper side of the carriage, and *E* its lower side. *F* is the longitudinal section at the middle of the carriage, and *G* the longitudinal section of the slide. *H* is the transverse section through the pin of the slide *a*, the carriage *b*, the slide *c*, and the traverse *d*, and pillar *e*. *f* is the deck plank, *g* is the opening in the middle of the traverse in which the middle part of the slide *h* runs, which guides the gun in the recoil; in an iron secured to the slide *c* a paul catches against the stop *k*, when the gun recoils from the shot, that the gun may be brought to its place till it is loaded; but as the bolt with which the paul *i* is fastened to the slide cannot resist the concussion which the paul receives, when the breeching after the recoil draws the gun forward again, the iron *θ* is fixed to the traverse close to the end of the paul to resist the concussion, and when it is loaded an iron bolt put into the hole *l* and the eye *m*, turns up the paul *i*, that the gun may run in board; and when the gun stands lashed within board, it is drawn so far in, that the paul *i* falls down into the stop *n*. In the hole *o* a bolt is put, between which and the end of the slide a wedge is driven in, by which the slide is secured between the paul and the bolt, so that it cannot come either in or out. *p* is a ring-bolt on each side of the traverse: through these rings a lashing is brought over the gun, by which it is so firmly secured to the deck that in the heaviest rolling it remains fixed and safe. From the lashing coming against the first and second reinforce mouldings, the muzzle of the gun does not move at all at the ship's side. *q* is a cleat which confines the breeching. In the outer end of the traverse is a score for the breeching which keeps the remaining part of it in its place, by means of the small bolts *r*, through the iron eye plates *s*. On each side of the pillar *e* is an iron plate *t*, through which a bolt *v* passes during the explosion, to prevent the traverse from rising from the deck. By means of the hand-spike *w*, which fits into the mortise *x*, the traverse is turned about the pillar *e*, and gives the gun its lateral training.

When the gun is required to stand fore and aft at the ship's side, the elastic catch *y* is raised, and the carriage is turned round the pin of the slide *a*. *z* is an iron cleat to secure the catch *y*, by which the gun in being fired always stands in the same direction as the traverse.

When lying in harbour, and it is required to have a clear deck, the traverses can be turned round so far towards a fore and aft direction, that with 36-pounders they do not project from the ship's side more than 9 feet: the guns can also, if required, stand athwartships out of their respective ports.

When a ship is to be armed, and the guns are to be laid on the traverse carriages, they must be hoisted over the gunnel, and lowered down through the main-hatchway of the upper deck, on thick plank laid on the beams over the main-hatchway of the lower deck, on which the carriage with the slide is placed, in a small traverse fitted for the purpose, when the gun is lowered down into its carriage and carried in a truck with four small wheels to its traverse at the ship's side.

END.

1804.

A table of cubes from 0,25 to 28,99 is given in the original, which it is considered quite unnecessary to insert in this translation.

ADDITIONAL APPENDIX.

When I had finished this work, it suggested itself to me, whether the parabolic method of construction here given with its rules might be considered by many as not sufficiently general, being adapted only to such fuller or sharper ⊕ sections as are constructed according to this principle, that their greatest fulness shall be just below the the water-line; but that it is not so, an example is here inserted, applicable to all kinds of ⊕ sections, of any form.

Form of a ⊕ section of a Frigate of 40 *Guns.*

The ⊕ section, Fig. 3, No. 1, is altered to the ⊕ section of the frigate of 40 guns, Fig. 4, No. 2, but containing the same area, same breadth at the water-line, and same depth as No. 1; also the displacement and length on the water-line the same, and with the same line of sections *h;* consequently, the areas of all the sections in No. 2 are equal to all the areas of the sections in No. 1, and the situation of the centre of gravity of the displacement in respect to length the same. They have the same sheer draught; the parts which are dissimilar are marked in No. 1 and No. 2; but although these two frigates are in all these particulars so much alike, and though No. 2 is $1\frac{1}{8}$ foot broader at $2\frac{3}{4}$ feet above the water-line, yet on account of the distance *b c*, Fig. 5, between the centres of gravity of the ships and their metacentres, the frigate No. 2 has its moment of stability one-sixth less than that of No. 1.

In the vertical line *E*, Fig. 5, the centres of gravity of displacement coincide at *a*, the centres of gravity of the ships and lading at *b*, and the metacentres at *c*, for both the frigates; the marks which are abaft this vertical line belong to the frigate No. 1, and those which are before it belong to the frigate No. 2; but the latter experiences somewhat less resistance in the water than the former, which may be found by the method given in this work.

Ordinates y	Ordinates of the Section-line h	Half areas of the Sections.	Ordinates of Ribband-line, c.]	
			Forward.	Abaft.
10	0,000	0,00	—	—
9	2,349	47,54	4,076	3,665
8	4,391	88,84	6,012	5,627
7	6,135	124,12	7,460	7,145
6	7,591	153,58	8,583	8,347
5	8,771	177,45	9,454	9,293
4	9,688	196,00	10,111	10,011
3	10,356	209,51	10,583	10,527
2	10,794	218,37	10,885	10,863
1	11,025	223,05	—	11,039
...	11,086	224,27	11,086	11,086

Forward $C = 0{,}373 \,.\, h + 0{,}627 \sqrt{\mathbf{h}\, h}$

Abaft ... $C = 0{,}522 \,.\, h + 0{,}478 \sqrt{\mathbf{h}\, h}$

Compare Table No. 40, page 3, for a frigate of 40 guns (which is No. 1) with the Table for the frigate No. 2; then it will be found that the difference is in the ordinates c of the ribband-line, which could not be inserted in Table No. 42, page 8, in which the general rules are found.

That the frigate No. 2 has one-sixth less stability than No. 1, arises from this cause: as both these frigates have their upper water-line of the same length and breadth in midships, and have the same area of ⊕ section, but No. 2 is fuller in the bottom; and as the displacement is to be equal in both, it follows, that as much as the displacement is increased in the bottom it will be diminished near the water-line, by which the load-water section is diminished from midships to both ends, and therefore $\int \frac{2}{3} y^3 \, d x$ is less: and this is the reason that the load-water section W does not agree with the general rule in Table No. 42; but the following rules are applicable, when the area of the altered water-section is used.

It should, however, be observed, that the breadth of the ⊕ section of a ship or vessel is never so suddenly diminished immediately below the water-line as the frigate No. 2; consequently the area of the water-line cannot be so considerably diminished; but it has been taken in the extreme only to show that the given method can be used for any form of ⊕ section:

likewise, in case it is required to have a vessel with the sides falling out as No. 2, and even more, and to have the area of the water-section as the frigate No. 1, the same method of construction may nevertheless be used.

As it is the fulness below which causes the diminution in the area of the water-section before and abaft the ⊕ section, this fulness below should be diminished, as shown by the ticked line *x x*, by which the half area of the ⊕ section is reduced by 3,156 square feet; and as the displacement is to remain constant, the same method is used which is inserted in Table No. 42;* whence $\mathfrak{h} = 10{,}93$, the exponent of the line of sections $n = 2{,}37$, by which the form is changed. The situation of the ⊕ section comes thus further forward, because the situation of the centre of gravity is to remain the same, by which the stations, as well as the areas of all the other sections, are altered; and when the operation is performed in all respects as above-mentioned, nearly the same area and form at the water-line is obtained as in the frigate No. 1; but there is nevertheless a deficiency in the stability, for the reason assigned in § 22. It is remarked, that the addition, *f*, to the water-line of construction *l* can be increased or diminished, either forward or abaft, by which the length of the whole water-line *L* is greater or less. See the Tables No. 33 and 42. In the formation of the drawing the occasion of such an alteration may appear, but whether it be required in the largest or smallest vessel, this addition can never exceed three-fourths, or at most one foot.

It may hence be inferred, that this method of construction is suitable to every kind of ⊕ section. H.S.B.

As all the drawings in this work are made by the same scale, and all the lengths *L* of the upper water-line between the rabbets of the stem and sternpost are the same for those constructed by the parabolic method, as for those whose form is founded on the direction of the line of relaxation, the scale has not been drawn on the sheer draughts of the parabolic sheer draughts.

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* By a little consideration of this Table a rule may be formed for any alteration which may be reasonably required. Also for ships of the line, from Table No. 33.

What is common to all printed drawings occurs here, namely, the unequal shrinking of the paper; all the lengths on the sheer draughts ought however to agree with those on the same drawing by the scale, and all the breadths on the body plans ought to agree with the scale of that plan; but the breadths on the body plans do not always agree with the breadths on the sheer draughts; they can, however, be always corrected by a proportional triangle. The greatest difficulty is in the heights, which may not agree with either scale, and those on the body plans may not be equal to those on the sheer draughts; but they are known by the abscissas **k** and **h** of the line of sections in Tables No. 15 and 22, and No. 33 and 34 for ships of the line, and in Tables No. 34 and 35, and No. 39 and 40 for frigates, in which Tables are also found the lengths *L* and *l* and breadths *B*.

On this account, if this work should obtain circulation abroad, it is particularly necessary that the whole text be translated into the language of the country, otherwise the complete advantage of the plates cannot be obtained: also on account of this method of construction being entirely new; it is also necessary that the translator should not only understand the two languages, but should know mathematics, and be well acquainted with the common method of constructing the drawings of ships, and also the practical part of shipbuilding, &c., in order that he may properly understand what is here treated on, so as not to commit such errors as the French translator of my Treatise on Shipbuilding, printed at Stockholm in 1775, did, in which translation, printed in 1781, he pretends that he found a gross error in § 9; but in 1793, which is 12 years after, a work appears, in which he recants what he had said, and shows that he himself had made the mistake; how should such conduct be regarded?

Although (as was said in the Introduction, page 144, vol. 3) I am not certain that the long measures given there are correct; I have however (as the difference does not appear to be considerable, and in order not to be without any knowledge of them) drawn the scales of long measure of the following nations, in proportion to the Swedish scale, by which the drawings in this work are made; namely, Portugal, France, Denmark, Rhinland, England, Sweden, Dantzic, Holland, and Spain, or Cadiz. See Fig. 6.

On the security of Ships' Decks without the use of Wooden Knees.

Great difficulty is experienced from the remarkable diminution in timber, in obtaining a sufficient number of oak timbers and oak plank of such size and length as to form a good combination; on the same account it is difficult to obtain a sufficient number of suitable oak knees, especially those which are large; and what constitutes in the greatest degree this difficulty is, that it is at this time very rare to obtain oaks, whose branches spread more than 45 degrees from the upright trunk of the tree, whereas they should at least form an angle of 60 degrees, and from that to 80 degrees, which latter kind is exceedingly rare; this want of oak knees has been supplied by the use of *knees of spruce fir,* which have been used in this manner; the trunk of the tree has been used as the principal arm of the knee, and its root as the branch or small arm of the knee.

All the firs which grow on level ground have their roots always perpendicular to the trunk, and are thus fit for lodging knees; but the roots of those firs which grow on sloping ground form greater or less angles with the trunk than right angles, according as the ground is more or less inclined; that is, the one grows up the sloping ground and the other down it, and it is the latter which are used as hanging knees. These roots have always sufficient thickness for the sidings, but the oak roots are always too thin in this respect. The roots of the fir are tougher than those of the oak, but are more liable to be rotten, and especially the trunk, on which account the fir knees cannot be used as lodging knees, in consequence of the expense which would be incurred in shifting them and putting new knees in their place; but this change can be accomplished without difficulty or inconvenience with the hanging knees.

In consideration of all these circumstances it is now more than twenty years since the decks of our ships of the line and frigates have been secured only with an iron hook, and a large bolt through the ship's side, instead of the lodging knee, and with a hanging knee of fir properly bolted; but this expedient also seems not to be able to be continued long, because it is easier to obtain 20 lodging knees than one hanging knee of the fir root: and it is on account of this very important reason that I have been led to consider, in what manner the decks of ships could be secured to the sides without the use of wooden knees.

As the want of iron can never be experienced, this is the only material with which the decks of ships should henceforth be secured to the sides; but in what manner it can be used to answer the purpose is the question which here offers itself for consideration.

The object is, first, to secure the ends of the beams of the decks to the ship's sides, so that they cannot separate from them.

Secondly, with the sudden rolling which a ship experiences from one side to the other, that the vertical angle which the beams make with the ship's sides may not be considerably altered. And thirdly, that if by the means adopted for this purpose any part may require repair, it may be conveniently done; and that this method may not in any way retard the working of the guns.

To obtain this object, the following method is proposed: see Fig. 7 and 8. Fig. 7 shows the side of a ship of 74 guns from the gunwale to the water's edge. Fig. 8 shows a transverse section of the ship's side, also from the gunwale to the water's edge. *A* is a lower-deck beam, *A* 1 the upper side of the beam; *B* an upper-deck beam; and *C* a quarter-deck or forecastle beam. The scale *F* gives the dimensions only of the woodwork. The ironwork with which the beams are secured to the ship's side is marked with a blue tint,* and is called the hooks; those which secure the ends of the beams to the ship's sides are called *horizontal hooks,* as *E e;* and those which during the ship's rolling prevent the alteration of the vertical angle of the beam with the ship's side from being considerable, are called *vertical hooks,* as *D d.* The part of these hooks which is fastened to the sides of the beams and extends to the ship's side, is called in the horizontal hooks the *arm,* and in the vertical hooks the *leg;* the part of these hooks which is fastened to the ship's side is called in the horizontal hooks the *toe,* and in the vertical hooks the *lip.* As it must be supposed that the dimensions of the beams of the deck have been given a proper proportion to the weight they have to sustain, and to the force which acts on them, it follows that the iron hooks should be in proportion to the beams; and as all the beams, as well the larger as the smaller, may be regarded as nearly similar, and the thickness up and down is the dimension which has the greatest effect on the strength of the beams, this moulded thickness of the beams in the middle has been divided into 13 equal parts, which I have called the module, and each module is divided into 8 parts; see Fig. 7, the beams *A, B, C.*

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* It has not been considered necessary to colour the ironwork in the figures of this translation.

By this small modular scale all the iron hooks in Fig. 7 and 8 are drawn; but as their dimensions cannot be clearly shown in these small figures, a larger modular scale *G* is made, by which the vertical hooks *D* and the horizontal hooks *E* are drawn. *h* is the side of the leg of the vertical hook, which is turned to the beam; *x* is the tenon which is let wholly into the beam, in which is a hole for the bolt *n* which passes through the beam, and is fastened on the other side of the beam with a ring and forelock; *g* is the outside of this leg; *k* is the side of the hook which is turned towards midships, at the upper end of which is the tenon, and at the lower end the blade *t,* in which is a hole for the bolt *l* which is driven through it, and is clinched on a plate without board, which is three times the diameter of the bolt in breadth, and in thickness half the module; *q* is the side of the arm of the horizontal hook *E,* which lies against the beam, and its tenon *x* is let wholly into the side of the beam; through the hole in it passes the bolt *v,* which is forelocked on the other side of the beam, *p* is the outside of this arm, *r* is the side of the toe which is turned towards the middle of the ship, the hole is for the bolt *o* to pass through, which is clinched without board, in the same manner as the bolt *l*; *s* shows the upper side of the hook together with its tenon *x*. The bevelling which the toe should have with the arm is determined by the greater or less tumbling home of the ship's side.

The small marks *o*, at the extremities of these iron hooks, show the holes for nails, with which they are fastened while the bolt-holes are being bored through the ship's side and the beams. The numbers on these figures show their dimensions in modules.

Each end of the beams of these three decks is secured to the ship's side with two horizontal and one vertical hook; but every beam of the lower deck has an additional vertical hook.

All the beams of the orlop-deck have a horizontal hook at each end, and the beams which are between the mizen and fore masts have two: all the bolts in the hooks of this deck are driven from without board.

These hooks must be made of good tough iron, and the tenon *x* should not be welded to the arm or leg, but be wrought in one piece, because the whole strength of this fastening depends almost entirely on the tenons *x* and the bolts which pass through the ship's side. The bolt-holes in both ends of these hooks should be drilled.

The quickwork between the ports is commonly of thin fir plank; but the plank through which the bolts of the vertical hooks pass must be of oak. It should also be observed, that however important it is that the end of the beams should fit close to the timbers, this should be the case only at the middle of the depth of the beam; but not at the upper or lower part, because the beams must necessarily be allowed a little angular motion in a vertical direction with the timbers.

It is found that neither the weight nor the expense of this method is greater than that of oak knees, and it is incomparably more durable.

I have now given the proportion and form of the ironwork, with which the beams should be secured to the ship's sides; but whether it is sufficiently strong can be known only by comparison with other ironwork, which withstands the same violent rolling of the ship, such as the chains, which after many years' experience have obtained the size at present used.

The bolts which pass through the blades of the vertical hooks should be proportioned to the chain bolts, because the direction of the force they have to resist is nearly the same, and as these bolts are given the same strength as the main chain bolts together with the preventer bolts, and the leg of the hook is of considerably greater strength than a link of the chains of the same mast; and as the number of these hooks is much greater than the number of chains for the three masts, and when is added to these the fastening of the beams of the upper deck, and of the quarter-deck and forecastle, which are also secured with vertical hooks, there can be no mistake in considering the security of the decks in respect to the transverse rolling of the ship as sufficient.

When the moment of the rolling of the weights is considered, which is as these weights multiplied by the square of their distances from the centre of gravity of the ship, which must be estimated in every direction, above, below, and at the sides of this centre; this relation of the moment of the rolling of the weights of the masts, &c., with the strength of the chains, is not unreasonably compared with the moment of all the weights in the ship in relation to the strength of all the hooks of the decks together.

The strength of this ironwork which secures the ends of the beams close to the ship's sides is known from experience to fully answer the object; and in case any ship has its centre of gravity below the water-line, whereby it receives sudden strains during the rolling, or when a ship loses its masts, and thereby has not the means of easing the rolling, on such account it is necessary to strengthen the decks with proper standards of the roots of fir, or of iron.

In case the beams are placed differently from those shown in the drawing, for example, one over each port, and one between every two ports, then the beam which is over the port can have only the two horizontal hooks, and that between the ports has two horizontal and two vertical hooks: in which case there is the same number of horizontal and vertical hooks as in the former disposition. This is the manner in which the beams of the decks should be secured to the ship's sides, by which the object mentioned above, in all the three conditions, is obtained: and it plainly appears that this method of security does not cause any hindrance in the working of the guns.

The use of iron instead of wood in securing the beams to a ship's side is not new: such has been for a long time the practice in France, but not in this manner.

To the note at page 281, vol. 3, must be added the following, namely (see Fig. 79), the resistance in this case forward is $= G\ D\ E\ C$, and the effect of the water abaft is $= G\ B\ F\ C$.

In what manner the Arching of a Ship may in a considerable degree be prevented.

When the form of a ship in the water, and its upper works, with the situation of the weights by which it is pressed down are considered, it is found that the volumes of water at the extremities of the ship do not in any manner counterbalance the weights which they have to sustain: consequently, if a ship were cut transversely into numerous parts, and each part were enclosed at its ends, so as to be water-tight, those parts nearest the extremities of the ship would sink much deeper, and the middle parts would rise higher out of the water, and would thus assume a different form from that shown in the drawing, namely, higher in midships and lower at the extremities. And as the form of a ship above or below the water cannot be otherwise than it is now and always has been, nor can the situation of the weights by which the ship is pressed down be altered, this defect can be obviated in no other manner than by a certain security through the whole length of the ship, not, however, wholly, but in a greater or less degree, depending on using the best means, and those which cause the least inconvenience. I will mention what has been done in this respect.

In the year 1759 two vessels were built at Stralsund, on the King's account, to be used in the Frische-haf in a war with the King of Prussia, the one about 100 feet long, and above 20 feet in breadth, and drawing not more water than 7½ feet: the other about 80 feet in length, and drawing 5½ feet water; they carried heavy armaments, especially at the extremities; and were made to row as well as sail: and on account of this armament and the many considerable weights, a strong combination of the fabric was necessary; but although their bottoms had the greatest fulness which could be reasonably allowed to them, they could not thereby obtain a sufficient displacement. It was therefore necessary to build them with timbers of as small scantling as possible; and as on this account they could not possess the necessary strength, especially in regard to their arching; in order to avoid this defect, the following method of security was considered best for them.

Parallel to the middle line of the vessels on each side, about half-way between the keelson and the orlop clamps, a strake of oak was laid on its edge six inches thick, along the whole length of the hold, let down an inch over all the timbers, the end of which extended to the deck, both forward and abaft, which was called the builge-strake, and which was fastened with bolts through the timbers and outside plank. Under the beams of the deck, perpendicularly over the builge-strake, was fixed on its edge a strake of fir along the whole length of the vessel six inches thick, with a score one inch deep for the beams, to which it was bolted, and was called the longitudinal shelf. Both ends of this shelf lay against the timbers of the frame, and its lower side on the builge-strake, to which it was coaked, both forward and abaft, and was fastened with bolts through the builge-strake, timbers, and outside plank. Between the builge-strake and the shelf vertical oak pillars were placed, at a distance from each other equal to their length; from the lower end of one pillar to the upper end of following pillar was placed a diagonal shore of fir. See more on this subject in the *Architectura Navalis Mercatoria*, printed at Stockholm in the year 1768, Plate 36, Fig. 5, and in the treatise on shipbuilding relating to it, printed at Stockholm in the year 1775, page 217: and as it was found that the object was obtained by the use of this diagonal trussing, which was adopted for the first time in this instance, all armed vessels, as well great as small, have been given a trussing in all respects similar to it.

For further proof of the effect of this method of preventing arching the following is inserted:—

In the year 1772 an armed vessel was built at Stockholm about the same size as that first named, but instead of the vertical pillars being of oak as in the former vessel, they were of fir in this vessel, but in all other respects as before. Immediately it was come off the slip it was found that it had straightened in the launching four inches, but within twenty-four hours after, it recovered so much of its former sheer that the sheer was straightened by only two inches. When it was examined in what manner it had taken place, it was found that the abutments of the shelf had pressed into the vertical fir pillars, nearly half an inch in some of them, and it was this yielding of the timber, which in some degree recovered itself, by which the arching was diminished; and on the lower end of the pillars against the wedges little or no indentation was observed. It should likewise be remarked, that the sliding plank on which the builge-ways ran, during the launching, did not extend to the edge of the water, but terminated about a foot above it, by which, when the middle of the vessel was at the end of the sliding plank, its foremost end had not the support of the water which was required, and became balanced; and it was just at this moment that the arching must have taken place.

Again.—About the year 1789 two larger vessels were built, each carrying one tier of 36-pounders; how it happened, that they had not the usual diagonal trussing, I do not know; they were used in the Russian war, and were much arched, and when in too short a period afterwards they received a large repair, it was found that the keel, which was 135 feet in length, had curved upwards in midships 2¼ feet, on which account the usual diagonal trussing in the hold was given to them.

In consequence of so much evidence on the effect of this method of security in preventing a ship's arching, there is every reason to believe that it will also produce the same effect on ships of the line, which become sometimes in a short time considerably arched.

Suppose it is required to make a similar disposition of security for a ship of the line, for instance, the ship of 110 guns given in this Treatise, and let Fig. 9 and 10 represent this arrangement.

As this strengthening should be applied at that place which is found most convenient in respect to the stowage of the hold, which it is most important to consider, and this is, to obtain a sufficient breadth for a certain number of water-casks, which is here considered to be four whole and one half cask on each side the keelson on midship pillars; if five whole casks were taken, the trussing would come too far out into the builge; besides, the nearer it comes to the middle of the ship the greater effect it has in preventing arching; therefore, when the diameters of four whole and one half cask are added together, with half the thickness of the midship pillar, and the whole thickness of the diagonal shores, it gives 18⅔ feet, which is the distance of the middle line of the ship from the outside of the diagonal shores. To show this trussing, the ship's side, from one end to the other, as far as this trussing extends, is supposed to be laid open. *a* is the frame timbers, *b* the ceiling, *c* the riders, *d* the builge-strake; *e* the fillings between the riders, builge-strake, and ceiling; *f* the shelf under the beams, which is in two thicknesses in breadth, which are bolted together to give shift to each other. Over these are laid three strakes of deck plank of such a thickness that they can be let down one inch over the beams, with bolts through these beams and the shelf; *g* is the vertical pillar, and *h* the diagonal or shore. In other respects the disposition of the pillars and trusses, &c., is as already described.

It must be further remarked, that all the parts which belong to this trussing, and terminate at the extremities of the ship, are there secured in the best manner to the ship: therefore not only must the ends of the builge-strake and shelf be coaked together at the extremities of the ship, but also the security there required is supplied by fillings lying longitudinally, which are not only coaked together, but also to the builge-strake and shelf; and which extend as far as where the shelf and builge-strake are about 2 or 2½ feet apart, by which the whole mass—namely, the shelf, filling, builge-strake, timbers, and outer plank, receive a sufficient number of bolts, which are driven from without and within, as *x x*. Likewise the fillings *e* under the builge-strake and between the riders are coaked to the ceiling, and the builge-strake to the fillings *e*; the combination of this disposition of trussing at both extremities of the ship cannot always be performed in the same manner; for example, if the trussing comes nearer to or farther from the middle line of the ship, or if the ship has greater or less fulness at the extremities, &c., each of these cases requires a different method; the circumstances of the part to be strengthened will determine the manner of performing it.

This method of security, when it is done strongly and is well executed, will certainly accomplish the object. That the effect in preventing arching is of consequence may be inferred hence: that when a coasting vessel, which was to carry a considerable armament, and which was more than 100 feet long, strengthened in this manner, was to be launched, and the day before going off, the wedges at the lower ends of the pillars were for the last time driven up, it occurred—that when all the wedges at the pillars fore and aft on both sides were hardened up at the same time, it produced this effect, that the upper end of the keel rose so much from the upper block that the block became loosened and moveable. It should also be remarked that this vessel was not deep in the hold, had only one deck, with light upper works and small scantlings.

As the quantity of all this timber and iron work required for this trussing would be equal to the weight of 1200 cubic feet of water, the three-decker would sink about $1\frac{1}{2}$ inch deeper in the water, by which the height of the battery would be so much the less; but as this should not be allowed, the drawing should be altered, so that the displacement, which is = 152875, may become = 154075 cubic feet; and the alteration can be made in this manner, namely—

To keep the ⊕ section and all the other sections at the same places as before, the exponent n of the line of sections remains the same, = 2,6385, whence the area of the ⊕ section is $= \frac{\overline{n+1}\,.\,D}{n\,l} = 1027{,}20$ (See the rules in Table No. 33, page 360, vol. 3, and the note page 23, vol. 4, for frigates of 40 guns). Let **h** be a tenth of an inch longer, then **h** is = 18,213, hence B is = 56,4; the breadth has thus obtained an increase of 0,13 foot.

The lowering of the metacentre, which is caused by the increase of the displacement, is counterbalanced by the small increase of the breadth; thus the situation of the metacentre is not changed. Perform the operations as for the ship of

110 guns, page 366, vol. 3, Table No. 34, then all the ordinates *h* of the line of sections will be obtained, and thence the areas of the sections and the ordinates *c* of the ribband-line.

From the two examples which are given at the beginning and end of this additional Appendix, it may be seen of what advantage the parabolic method of construction is, especially in the accuracy and ease with which very many alterations in the different elements can be made, to obtain the object and qualities required; and this is the additional evidence which was spoken of at the conclusion of § 53.

The following observation will be here inserted, which ought to have been in a note to § 42, page 358, vol. 3; in lines 23 and 24 it stands—"*that their common centre of gravity may coincide in T?*" The note ought to be this—namely, As all nations do not fit their ships in the same manner, by which the common centre of gravity of all the weights neither is, nor can be, at the same place longitudinally; and as it also happens, that vessels are built for certain purposes which require some particular fitting, by which the situation of certain weights is fixed, and for which there is scarcely room, it is therefore particularly necessary that, after the magnitude of the vessel has been found as correctly as possible, a copy of the draught should be made, in which all the weights and ballast should be placed in their proper situations in the vessel, by which the common centre of gravity of the displacement may come to its proper place longitudinally; otherwise it would be necessary to place the ballast where it should not be, in order to give to the vessel its determined trim.

In conclusion: as the method of the construction of ships which I have given above, which is equally applicable to particular as well as general cases, is the fruit of many years' research, without being grounded on other authors; and as this work must inevitably, at my great age, be the last effort of my various endeavours to perfect the science of ship-building, I may be allowed to dedicate it as my *testament* or memorial of what I have been able to contribute to it, to all enlightened admirers of this noble science.

1806.

Art. II.—*On Rotatory and Rectilinear Motions; with Observations on the Effects of those Forces which are, in some cases, brought into operation by them.* By Mr. Lloyd, of H. M. Dock Yard, Portsmouth, formerly of the School of Naval Architecture.

It is well known that the rotatory motion of a body, in free space, always takes place round an axis passing through its centre of gravity. It is true also, when bodies are immersed in fluids, and acted on by variable forces. This fact, however, has been frequently denied, by men, too, possessing considerable knowledge of subjects connected with naval science.

Mr. Wilson, of the Navy Office, in his "Observations on a Ship's Rolling," No. 9, page 81 of this work, after having stated that some writers consider that a ship in rolling turns round an axis passing through the centre of gravity, says, "On the contrary, other writers, and Chapman among them, whose name alone is a host on subjects of naval science, consider the axis of rotation to pass through the metacentre."

Every person who has the pleasure of knowing Mr. Wilson must be well aware that the solidity of his judgment, arising from the cautious, philosophic manner in which he avails himself of his vast information, causes the greatest respect to be paid to his opinions: for this reason, it is the more desirable to examine the correctness of what he has advanced.

In the above quotation, Chapman is said to have sanctioned the opinion, that a ship in rolling does not revolve round an axis passing through the centre of gravity; it is generally difficult to prove a negative fact, but in this case it almost amounts to the same thing, if it can be proved that he asserts the contrary of what is here ascribed to him; for he is not likely to be inconsistent with himself, and even if he should be, his authority on this point would be neutralised.

In Chap. 3 of his "Treatise on Ship Building," translated by Professor Inman, in treating on the rolling of ships, and on the method for finding the length of the isochronal pendulum, he says, page 26, "it is sufficiently clear that the metacentre g or G may be considered as the centre of percussion." He could not, therefore, consider that the ship revolved round an axis passing through that point. But he expressly says, in several places, that the point through which the axis passes is the centre of gravity. Thus, page 24, "But the ship during the inclination is supposed to revolve round its centre of gravity." Also, page 26, "The angular motion of a ship round its centre of gravity being stopped . . . . but as the vessel, without farther opposition, is supposed to roll back round its centre of gravity . . . . ." From these passages, and others of a like tendency, it is inferred that Chapman cannot be considered as having entertained the opinion ascribed to him.

Perhaps the clearest manner of showing that the axis of rotation must pass through the centre of gravity, and of explaining, in some particular instances, the effect of forces acting on a ship, will be first to inquire into the motions of a body in free space, acted on by any number of constant forces. For, the truth of the conclusions arrived at in this case being capable of strict demonstration, they may be taken as premises, from which it will be easy to draw other conclusions applicable to the motions of a ship.

It is unnecessary to prove, that if any number of forces act on a body, the pressure on the centre of gravity, and therefore its motion, will be the same as if they were all collected at that point. It is also well known that any force, the direction of which does not pass through the centre of gravity, will have a tendency to turn the body round an axis passing through it; which axis is perpendicular to the plane passing through the line representing the force and the centre of gravity.

As these two motions are totally independent of each other, they may be considered separately: that is to say, the rectilinear motion of the centre of gravity as if no rotatory existed, and the rotatory motion as if the centre of gravity were fixed.

Let three planes be supposed to pass through the centre of gravity, so that every one may be perpendicular to the other two: it is evident that the three lines formed by the intersections of the planes will likewise be perpendicular to one another. All forces not acting in directions parallel to these lines, can be resolved into others which are in those directions. This is immediately seen by conceiving those lines representing the forces, which, if produced, would cut the *three* planes, as diagonals of rectangular parallelopipeds, made up of planes parallel to those passing through the centre of gravity: and those which would cut *two* of the planes only, as hypothenuses of right angled triangles, whose sides are parallel to those two planes, and the planes of the triangles parallel to the third one.

Having resolved the whole of the forces into others, parallel to the lines formed by the intersections of the planes passing through the centre of gravity, let the sum of the resolved forces acting in the same direction be taken. Now, suppose a rectangular parallelopiped to be so constructed that three of its planes shall coincide with the three planes passing through the centre of gravity, and its length, breadth, and height be equal to the sum of the resolved forces in those directions respectively; then its diagonal, drawn from the centre of gravity, will represent a force which, acting at that point, would, in the same time, generate the same rectilinear motion as would be generated by the combined action of the original forces.

It is not necessary, however, to have recourse to construction to determine the length or direction of this diagonal, as it is at once seen that the length is equal to the square root of the sum of the squares of the three dimensions of the parallelopiped; and its direction is known as the cosine of the angle it makes with any line formed by the intersections of the planes of the parallelopiped, is equal to that line divided by the diagonal.

In order to determine the effect of the forces in producing rotatory motion, the centre of gravity is supposed to be fixed.

The effect of a single force in producing rotatory motion, is in proportion to the force multiplied by the line joining the centre of gravity and the point at which the force acts, multiplied by the sine of the angle made by this line and the one in the direction of the force. If the whole of the forces acted in one of the three planes passing through the centre of gravity, they would turn the body about an axis formed by the intersection of the other two; and their joint effect would be found by taking the effect of the forces separately, and adding them together.

As the axis round which any force tends to turn the body, is perpendicular to the plane passing through the line of the force and the centre of gravity, it is evident that the application of any force which does not act in the plane in which the other forces act, causes the body to turn round an axis inclined to the former one. Let us, therefore, inquire how the direction of the axis may be determined, round which the body revolves, by the combined action of forces which are neither in the same plane nor in parallel directions.

All the forces being resolved into others perpendicular to the three planes passing through the centre of gravity, let the effect of the resolved forces in turning the body round the axis coinciding with the intersections of these planes, be determined separately. This is done by drawing lines from the points at which they act perpendicular to the axis, round which their effect in producing rotatory motion is to be calculated; and by taking the sum of the products obtained by multiplying each resolved force by its corresponding line thus drawn, and by the sine of the angle contained by this line and that of the resolved force. Or, which amounts to the same thing, by taking the sum of the resolved forces multiplied by their respective perpendicular distances from the plane to which they are parallel, and in which the axis lies.

Two of the axes are, of course, supposed to be free, while the effect of the forcss in causing rotatory motion round the third one is being determined.

Now, it is evident that if the relative distance of a force from the three axes be the same, its direction remaining unaltered, the same rotatory motion will be produced if the force vary inversely as its distance from them. Let a line, then, be drawn in the plane of two of the axes, and parallel to one of them, at any distance from it, by which distance divide the measure of the effect of the resolved forces in producing motion round this axis. A force equal to the result will, if applied at any part of the line thus drawn perpendicular to the plane passing through it and the centre of gravity, have the same effect in turning the body round *this* axis as the resolved forces.

Let this force be supposed to move parallel to itself along this line, until the force multiplied by its perpendicular distance from the other axis, becomes equal to the measure of the effect of the resolved forces round it. This force, then, will have the same tendency to produce motion round the *two* axes as the resolved forces.

At the point at which this force acts, and perpendicular to it, let a second force be applied in any direction, not passing through the centre of gravity, so that its efficacy in producing motion round the third axis may be equal to that of the resolved forces. The diagonal of the lines representing these two forces will represent one, which alone will generate the same rotatory motion as the original forces, and round the same axis. This axis, as was before stated, perpendicular to the plane passing through the centre of gravity and the line of the force.

Let a line equal and parallel to this one be drawn from the centre of gravity.

We have already found a line representing a force at the centre of gravity, the effect of which in producing rectilinear motion is equal to that of the original forces. The line, therefore, joining the extremity of these two will represent the force at the centre of gravity, which acting in conjunction with that producing rotatory motion, will produce the same effect as the combined action of the whole of the original forces.

It has been said that the force producing motion round the third axis may be applied in any direction; the quantity and direction of the force to be applied at the centre of gravity are alone affected: for it will be seen, by a little consideration, that the plane passing through the resultant and the centre of gravity will always remain the same; as also will the resultant multiplied by its perpendicular distance from the centre of gravity.*

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* It may be thus demonstrated:—Let *c* Fig. 11 be the centre of gravity of the body, through which the axis passes perpendicular to the plane of the paper, and *a* the point at which the force acts in the same direction: at the point *a*, also, the other force is to be applied in any direction in the plane of the paper. The resultant of these two forces is always in the same plane.

Let *a f*, *a f* represent two forces, which have the same effect in turning the body round the axis passing through *c*. Let *a f* be perpendicular to *a c*.

As we know the situation and direction of a force which will produce the same rotatory motion as the whole of the original forces, the point may easily be found at which, if any given force were applied, the same effect would be produced. It immediately follows from this, that if the motion of the centre of gravity be perpendicular to the axis round which the body revolves, it becomes unnecessary to apply a force at the centre of gravity, as the situation of the one producing rotatory motion can be determined, so that its quantity and direction shall be such that it will generate the necessary rectilinear motion.

We see, therefore, that two forces, and sometimes one, can be found, which will produce the same effect as any number of constant forces acting in various directions.

It will, no doubt, be at once admitted, that the same effect which is produced by the action of fluids on a body may be produced by the action of an indefinite number of variable forces acting at different points. If so, it immediately follows, from what has been shown, that if at any particular instant the forces be supposed constant, one force may be so applied as to have the same effect in producing rotatory motion as the combined action of the whole of them; and if this force should not produce the same motion of the centre of gravity, it may be produced by applying at that point a second force to act in

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Draw $c\,b$ perpendicular to $a\,f_{,}$, and join $f\,f_{,}$.

$$\text{Now, } a\,c \times a\,f = a\,f_{,} \times c\,b$$

$\therefore\ a\,c : c\,b = a\,f_{,} : a\,f$, and the angles $f\,a\,f_{,}$, $a\,c\,b$, being equal, the triangles $f\,a\,f_{,}$, $b\,c\,a$, are similar. $a\,f\,f_{,}$ is therefore a right angle. Hence $a\,c$ is parallel to $f\,f_{,}$.

At f and $f_{,}$ let lines be drawn parallel and equal to the line representing the force at a, which is perpendicular to the plane of the paper. The lines joining the point a and the upper extremities of these lines will represent the resultants. It is evident that these resultants and $a\,c$ are in the same plane, since $a\,c$ and the line joining the extremities of the resultants are each of them parallel to $f\,f_{,}$.

It is also evident, from similar triangles, that the resultant, of which $a\,f$ is the vertical projection, $\times\ a\,c =$ the resultant of which $a\,f_{,}$ is a similar projection, $\times$ the perpendicular drawn to it from the point c. The effect, therefore, of the resultant in producing rotatory motion round the vertical axis passing through c, is the same whatever be the direction of $a\,f_{,}$.

conjunction with the first. At the next instant either two forces may be so applied as to produce the same effects as the variable forces, and so on for every successive instant of time. It is evident, then, that by the action of two forces the quantity and direction of which are continually varying, the same effects may be produced as by the action of fluids, either in combination or not, with the action of any other forces whatever.

The only question now is, What effects will be produced by these two variable forces? It is quite certain that the one at the centre of gravity can neither accelerate nor retard the rotatory motion, nor can it alter the position of the axis round which it takes place. The rotatory motion will, therefore, be the same, in every respect, as if the body were acted on by one force only.

If the quantity and direction of this force be supposed constant during successive increments of time, the axis round which it will tend to turn the body during each of them will pass through the centre of gravity; that is to say, the centre of gravity will have no rotatory motion communicated to it. This is true, however small those increments are taken; it is, therefore, true when they are evanescent, or, in other words, when the force is constantly varying.

It may, perhaps, be unnecessary to remark, that the centre of gravity cannot remain at rest, unless the resultant of all the forces supposed to be collected at that point becomes equal to nothing.

Although the motion of the centre of gravity and the rotatory motion do not affect each other, yet, in some cases, forces which are consequent upon them being brought into action, produce effects on both these motions.

In order to illustrate this observation, we will take two or three instances in which the said forces have been overlooked.

Mr. Major, in the "Annals of Philosophy," No. 66, page 411, proposes the following method for finding the height of the centre of gravity of a ship:—

An horizontal lateral force is applied at some part of the mast or topmast, and the angle of the ship's inclination noted. The ship is then allowed to resume her upright position, and by means of a greater force, applied in the same manner as the first one, but at less height, she is inclined to the same angle as before.

The effect of each force, in inclining the ship, is as the force multiplied by the line drawn from the point at which it acts at right angles to the longitudinal horizontal axis passing through the centre of gravity, multiplied by the cosine of the ship's angle of inclination. The angle of inclination being the same in both cases, it is inferred that the first force × the line drawn from the point at which it acts perpendicular to the axis × cos. of the angle of inclination = the second force × the line drawn from the point at which it acts perpendicular to the axis × cos. of the angle of inclination. The cos. of the angle of inclination may be struck out, as it is found in both sides of the equation. The distance of the two forces from each other, as well as the forces themselves, being known, the distance of the axis from either of them may be calculated.

Now, those inclining forces which are brought into operation by the lateral motion are not taken into account. Let us inquire what effect these forces will produce.

It is very evident that the lateral motion will continue to increase until the horizontal lateral force, arising from the resistance of the water, becomes equal to the horizontal force which produces the motion. These two forces must be in the same vertical plane, since there is no motion round a vertical axis. To this plane the vertical force arising from the resistance of the water may be transferred, its distance from the longitudinal axis remaining the same; for it is not necessary to estimate its effect in producing motion round a transverse horizontal axis.

The lateral and vertical forces of the water either assist in inclining the ship, or the contrary, according as the lines in their direction, when produced, pass below or above the longitudinal axis passing through the centre of gravity. We have no means of ascertaining the absolute effect of these forces, as we know neither the height of the longitudinal axis nor the amount of the vertical force, nor the points at which the two forces act. We may, nevertheless, see in what manner they affect the result of the experiment.

Let the resultant of these two forces be produced until it intersects the longitudinal plane passing through the middle of the ship. The forces may be supposed to be transferred to the point of intersection, the horizontal force being equal to the one applied to produce inclination, and the vertical force unknown. The effect of the vertical force is as the force × the distance of the point at which it acts from the axis × sine of the angle of the ship's inclination. If the angle of inclination be small, the effect of this force is inconsiderable when compared with that of the horizontal one; we will therefore, for a moment, disregard it.*

The effect of the horizontal force is as the force × the distance of the point at which it acts from the axis × cos. of the ship's inclination. According as this force passes above or below the axis of rotation, this expression for its effect must be subtracted from, or added to that for the effect of the horizontal force applied at the mast. In this case, therefore, the result of the experiment would be an approximation to the height of that point in the vertical longitudinal section, through which the line of mean resistance passes.

If the vertical resistance be too great to be neglected, the point found would be something above or below the one just mentioned, according as this point is above or below the axis passing through the centre of gravity; thus removing the point still farther from this axis.

If the inclining forces were applied perpendicular to the plane of the masts, then, whatever be the inclination of the ship, the point determined would be the one in the vertical longitudinal plane through which the resultant of the water passes. For, in this case, the resultant may be resolved into two forces, one perpendicular to the inclining force, and the other parallel to it.

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* It must be remembered, that when the effect of the vertical force is spoken of as being small in comparison with that of the horizontal one, it it after those forces are transferred to the point where their resultant cuts the longitudinal plane passing through the middle of the ship.

We see, therefore, that when there is no vertical force to be taken into account, the situation of the point found has no relation whatever to that of the centre of gravity; and when there is a vertical force, the higher the centre of gravity is situated the lower will be the point found by this experiment, and *vice versa.**

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* If these observations be not sufficiently clear, they may be rendered so by reference to a diagram.

Let the vertical plane passing through the two inclining forces $a\,b$, $c\,d$, Fig. 12, cut the longitudinal axis passing through the centre of gravity in the point o. To this plane the vertical force arising from the resistance of the water is transferred. The horizontal force necessarily acts in this plane. r is the point in which the resultant of these two forces cuts the longitudinal plane passing through the middle of the ship, and to which point they are transferred. $r\,m$, $r\,h$ represent those forces when the ship is inclined by the force $a\,b$; and $r\,n$, $r\,k$, when she is inclined by the force $c\,d$. $r\,m$ and $r\,n$, for the reason before given, are equal to $a\,b$ and $c\,d$ respectively, and $r\,h$ and $r\,k$ unknown.

Mr. Major assumes:—

$a\,b\,.\,a\,o\,.\,\cos\theta = c\,d\,.\,c\,o\,.\,\cos\theta$, θ being the angle of inclination.

Dividing both sides by $\cos\theta$, substituting $(a\,o - a\,c)$ for $c\,o$, and transposing,

$$a\,o\,(c\,d - a\,b) = c\,d\,.\,a\,c$$

$$a\,o = \frac{c\,d\,.\,a\,c}{c\,d - a\,b}.$$

Now the true equation is,

$$a\,b\,.\,a\,o\,.\,\cos\theta - r\,m\,.\,r\,o\,.\,\cos\theta - r\,h\,.\,r\,o\,.\,\sin\theta =$$

$$c\,d\,.\,c\,o\,.\,\cos\theta - r\,n\,.\,r\,o\,.\,\cos\theta - r\,k\,.\,r\,o\,.\,\sin\theta$$

By transposing $r\,k\,.\,r\,o\,.\,\sin\theta$, dividing by $\cos\theta$, and substituting for $r\,m$ and $r\,n$ their equals $a\,b$ and $c\,d$,

$$a\,b\,.\,a\,o - a\,b\,.\,r\,o + (r\,k - r\,h)\,r\,o\,.\,\tan\theta = c\,d\,.\,c\,o - c\,d\,.\,r\,o$$

By substituting $(a\,o - a\,c)$ for $c\,o$, and $k\,h$ for $(r\,k - r\,h)$ $a\,b\,.\,a\,o - a\,b\,.\,r\,o + k\,h\,.\,r\,o\,.\,\tan\theta = c\,d\,(a\,o - a\,c) - c\,d\,.\,r\,o$

Or, $(a\,o - r\,o)\,(c\,d - a\,b) - k\,h\,.\,r\,o\,.\,\tan\theta = c\,d\,.\,a\,c$

Dividing by $(c\,d - a\,b)$ and putting $a\,r$ for $(a\,o - r\,o)$ we have,

$$a\,r - \frac{k\,h\,.\,r\,o\,.\,\tan\theta}{c\,d - a\,b} = \frac{c\,d\,.\,a\,c}{c\,d - a\,b}$$

In No. I. of this work, page 15, we meet with the following method for finding the centre of gravity:—

"Another method proposed for finding the centre of gravity is by causing the ship to roll, by the crew going together from side to side, and having persons in boats at the stem and stern-post, to observe the points that do not partake of a circular motion, which are the poles of the axis of rotation, which passes through the centre of gravity of the ship."

It is then added, "There is, however, a difficulty in observing these points on account of the rising and falling of the centre of gravity, in consequence of the inclination."

This case is the reverse of the other, in which the rotatory force, brought into operation in consequence of the rectilinear motion, was neglected. Here the rectilinear motion, caused by the resistance of the water in consequence of the rotatory motion, is neglected. This resistance would cause the centre of gravity to move from side to side; so that the fixed point, if indeed any point be fixed, must lie higher than the centre of gravity.

Independently of this consideration, the experiment would be inconclusive, inasmuch as the situation of the centre of

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If $\frac{kh \,.\, ro \,.\, \tan\theta}{cd - ab}$ be so small that it may be neglected, then $ar = \frac{cd \,.\, ac}{cd - ab}$ nearly. Hence, in this case, instead of the distance of the centre of gravity from the point a being equal to $\frac{cd \,.\, ac}{cd - ab}$, we see that this expression has no relation to the situation of the centre of gravity, but to that of the point where the resultant of the water intersects the longitudinal plane passing through the middle of the ship. If $\frac{kh \,.\, ro \,.\, \tan\theta}{cd - ab}$ be too great to be neglected, then the point determined by this experiment will be above the point r, as was before stated; and *cæteris paribus*, the lower the centre of gravity is, the higher will be the point determined, and, therefore, the farther removed from it.

If the resultant of the water pass below the centre of gravity, the expressions for the effect of the vertical and horizontal forces will be positive instead of negative; in other respects the same process is applicable, and similar conclusions will be arrived at.

gravity itself is continually altered by the crew going from side to side.

It has been shown that if, by means of any force which is not vertical, a ship be made to incline, the lateral motion causes a horizontal and a vertical force to be brought into operation. The degree of inclination must evidently depend, in some measure, on the quantity and direction of their resultant.

Atwood, however, says, in page 305 of his "Philosophical Transactions," 1798:—

"It is here necessary to observe, that the force of stability and the measure of it, the subject of investigation in the preceding pages, is wholly independent of the water's resistance, which co-operates only while it is inclining, and wholly ceases as soon as the vessel has attained to its greatest inclination, at which it is supposed permanently to remain in a state of equilibrium, the inclining force being exactly balanced by the force of stability. This observation will obviate any difficulty that might possibly occur from the principle stated in page 213; which is, that if the zone W H F C,* comprehending that portion of the sides of a vessel which may be immersed under and may emerge above the water's surface, should be the same in two vessels, the stability will be the same at all equal angles from the upright, whatever shape be given to the form of the volume immersed, which is situated beneath the said zone, provided the vessels be in other respects similarly constructed and adjusted: if, for instance, the keel of one vessel should be very deep under the body of the vessel, the keel of the other being of the ordinary dimensions, the deeper keel will oppose an increased resistance to the inclination of the vessel only while it is inclining, so as to make it heel slower; but will not alter the angle of permanent inclination caused by a given force of the wind, or other uniform power: which inclination depends entirely on the stability which has been determined in the preceding pages, and has no relation to the resistance of the water, which arises from the vessel's inclination round its longer axis."

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* This will be easily understood without a figure.

It is true that the resistance of the water does not affect the *stability*, but it affects the *inclination* of the ship, which, in a practical sense, is the same thing; and of two ships with the same masts and sails, the one which, with the same force of wind, inclines to the less angle, may be said to possess greater stability than the other.

But Atwood not only says that the stability is not affected by the resistance of the water, but also that it "wholly ceases as soon as the vessel has attained to its greatest inclination." The resistance occasioned by the rotatory motion of course ceases with that motion, but the resistance occasioned by the lateral motion always exists; which resistance most certainly would alter the angle of permanent inclination, unless the line of mean resistance passed through the longitudinal axis passing through the centre of gravity of the ship.

It is also said, that the only effect produced by a deep keel under a vessel will be "to make it heel slower, but will not alter the angle of permanent inclination caused by a given force of the wind, or other uniform power." Now, a deep keel not only increases the lateral resistance, but it causes the line of mean resistance to pass through a point at a greater distance from the inclining force. For which reasons such a ship, under all circumstances, must incline at a greater angle than one which has a keel of the ordinary dimensions.

If the effect produced on the inclination by the resistance of the water needed any farther illustration, we may suppose a prism, generated by the motion of an isosclles right angled triangle, to be so placed in the water that the side generated by the base of the triangle may be in the plane of the water's surface. Let it move laterally. If there be no inclination, the mean resistance will pass through the line formed by the intersection of the plane of the water's surface with a vertical one bisecting the prism lengthways. The mean resistance on a vertical plane, immersed the same depth as the prism, would pass through a point half its depth below the surface of the water. Hence in producing inclination, the effect of the same inclining force at the same height above the water's surface, and acting in conjunction with the resistance of the water, would be less in the former case than in the latter, by the force multiplied by half the depth of the plane, or of the prism.

We see, also, that the effect of a similar force brought into operation by the ship's moving in the direction of her length is such, that an horizontal force in the same direction, applied at a point at a considerable height, the *point velique* produces no depression.

ART. III.—*Observations relative to the late experimental Cruises of Ships of War, with a view of showing by what means a future experimental Trial of Ships may be rendered subservient to the advancement of the Science of Naval Architecture.* By Mr. WILLIAM HENWOOD, *of his Majesty's Dockyard, Portsmouth.*

AN account of the principal dimensions of ships of various classes in the British navy, given by Mr. Bennett in the fifth Number of this work, sufficiently shows that the lengths and breadths of ships of war have always been determined in a purely arbitrary manner. It does not appear that any well-recognised principle or rule has hitherto been either propounded or adopted, for the guidance of constructors of ships, in fixing on the length, breadth, and depth of a vessel. The old method, of making a ship a little longer, or a little broader, or, possibly, a little deeper, or the reverse, than some favourite French, Swedish, American, Spanish, or Dutch ship, has been universally followed by English shipbuilders.

It appears highly desirable we should endeavour to discover and fix the limits beyond which the length and breadth and depth of a ship should not be carried. This, it is considered, can be done in no other way than by instituting a much more minute and strictly scientific comparison between ships of the same class, of different dimensions, than has ever yet been done. It is perfectly certain we possess the means of finding out the causes of those palpable differences in the performances of ships at sea, which excite surprise and amazement in many individuals, and dispose them to conclude the subject is involved in impenetrable mystery. All that can be required is, that the knowledge we are already in the possession of should be fairly brought into play, and allowed full scope for its exercise.

It is much to be regretted that so very few facts have been elicited by the several recent experimental cruises of our ships of war. The causes of this circumstance appear to the writer to be a subject deserving of minute inquiry and full exposition. The expense of sending a number of ships to sea, for the express purpose of finding out which is the fastest sailer, or the best ship, is so great, that if any method can be suggested to ensure the obtaining a satisfactory result from any future trial of the sailing qualities of ships, it is to be hoped it will meet with the attention it may deserve.

The experimental trials of the Orestes, Champion, and Pylades, corvettes of 18 guns, in the years 1824 and 1825, terminated, unfortunately, before it had been so fully ascertained, as was to be desired, which of the three was the best ship. The result of the first cruise was, that the Champion was, on the whole, rather the best of the three. Several alterations were made in the other two ships, previously to their sailing the second time, but no alteration was made in the Champion:—she sailed the second time precisely as she did the first; and she was, through this circumstance, a standard of comparison by which the good or bad effects of the alterations made in the other ships could be manifested. At the end of the second cruise, it was most obvious that both the Orestes and the Pylades had been exceedingly improved by what had been done to them; and that the Orestes was decidedly the best ship of the squadron. Previously to the third cruise, all the ships were altered, and no standard of comparison was preserved; and the result of the third cruise was, in consequence, rendered altogether a matter of uncertainty. Had no alteration whatever been made in the Orestes after the second trial, it would have been proved whether what had been done to the Champion and the Pylades had been productive of benefit, or the contrary.

A similar want of a test, by which the good or the bad effects of the alterations made in the ships of the experimental squadron of 1827, (of which an account was given by Mr. Bennett, in the article above referred to, and by Mr. Chatfield, in the seventh Number of this work,) appears to have existed. It was stated in No. 73 of the "Quarterly Review," relative to the result of the trials of this squadron, that the gallant admiral who commanded it would not decide which of the ships was better than the others. Reflection on these and other circumstances, which need not be mentioned, has led the writer to conclude that it would be possible, in a future trial of rival vessels, to obtain a satisfactory and indisputable account of the relative merits of a number of ships, if the following considerations and mode of proceeding were to be attended to and observed.

It is essentially necessary that all the ships of an experimental squadron should proceed to sea as nearly as possible under the same circumstances. They should carry the same proportion of stores and other weights, with the exception of ballast, the quantity of which must be sufficient, in conjunction with the other weights, to produce the desired degree of stability. The bottoms of the ships, also, should be equally clean; and the officers to command them should be selected solely on account of their professional ability. Unless these particulars are attended to, it is vain to expect satisfactory and accurate results from an experimental cruise.

But there are other considerations which especially demand the attention of those who aim to find out the relative excellence of ships in sailing. It is well known that a fore-and-aft rigged vessel has a great advantage over a square rigged vessel in sailing by the wind. And there is every reason to believe the superior sailing of the Columbine by the wind, during her experimental cruising, was owing, in a great degree, to the means afforded her of bracing her yards so very much nearer to the fore-and-aft direction than any other vessel of the squadron could do. Mr. Bennett has stated, in his paper above referred to, that "the Columbine's main-yard was braced to an angle of 19°, and frequently to an angle of only 17°;" and that "the angle to which the main-yards of most of the ships of the squadron were braced, when sailing close hauled, varied between 27° and 30°. The Columbine's sails appear therefore to have been trimmed somewhere about ten degrees nearer the fore-and-aft direction, than the sails of the other ships of the squadron. This difference in the angles to which the sails of those ships were trimmed is so great, that it is most deeply to be regretted, when so favourable an opportunity presented itself of ascertaining a most important question,—whether the fast sailing of the Columbine was or was not mainly owing to the unusually sharp bracing of her yards,—the circumstance should have been allowed to pass unregarded. If any of the other ships of the squadron, which were not deficient in stability, had had the same means afforded them of bracing their sails to the same angle as those of the Columbine, it is highly probable the latter ship would not have appeared to so great an advantage as she is said to have done. The advantage obtained from bracing the yards sharp would very possibly be neutralised in a crank ship, by the increased heeling which the sails, when so trimmed, would necessarily occasion.

It is also well known that many ships have been much improved in sailing by the wind, through an additional depth of keel. The beneficial effect of an increased depth of keel, in preventing a ship from falling to leeward, was most clearly evinced in the Pylades, during the second and third experimental cruises of 1824 and 1825. The ship was remarkably leewardly during the first trial; and was rendered quite as weatherly as either the Orestes or the Champion, by an addition of 12 inches of depth to her keel. There was no other alteration made in the Pylades which could have produced the very great difference there was, during the last two cruises, in her sailing by the wind.

The resistance to leeway must certainly depend on the area of the vertical and longitudinal section of a ship under the water. And, so far as we know, the ordinary differences in the forms of the bottoms of ships of the same size can have but very little, if any, effect in increasing or in diminishing the lateral resistance. We may, in general, safely leave the form of the ship out of the question, and assume that the resistance to leeway depends on, and is proportionate to, the mean length of the ship below the line of floatation, multiplied by the mean draught of water. If ships of the same class have not the same means afforded them of opposing leeway, one ship may always be found to sail faster than another, when sailing off the wind, and to be very leewardly in comparison with the same vessel when close hauled; whilst nothing but an additional false keel is wanting to make her in all circumstances the fastest and most weatherly ship. It accordingly appears to be of importance that, in a future experimental squadron, all ships of the same class should be required to have such a depth of false keel as will make the product of the mean length, and the mean depth of the immersed part of the body, equal, or nearly so, in them all. Were this condition to be made indispensable in a future experimental squadron, it would be proved which of the ships met with the least *direct* resistance; and this is the point the most desirable to be correctly ascertained.

Having stated what appears of principal importance to be attended to, in fitting out ships for a trial of sailing; a few observations will now be offered with a view of showing how it is considered to be quite possible to arrive at a more precise and satisfactory conclusion respecting the comparative merits of rival ships, than has in any instance been obtained from an experimental squadron. It has almost invariably occurred after a number of ships have returned from a trial of their sailing, some degree of superiority has been claimed by almost every one of them, which has not been acknowledged by the others.

A discrepancy in the opinions formed by different individuals respecting the comparative sailing qualities of ships, appears to arise out of the difficulty of correctly determining distances at sea; and the difficulty of accurately estimating the apparent loss of some ships, and the apparent gain of others, occasioned by a shift of wind, so as to be able to make a just allowance for such apparent, though unreal, loss of some, and gain of other ships.

The difficulty of judging satisfactorily how far distant any ship is from another at sea, is notorious. It is well known that objects, whether viewed on land or at sea, appear nearer or more distant than in reality they are, in proportion as the atmosphere is more or less clear. It is also well known, we form a judgment of the distance of an object from us, when one or more objects intervene, very different from that which we form when nothing intervenes. Philosophers have long since remarked, that the sun or the moon when seen by the naked eye near the horizon, appears much nearer to us than when beheld through a tube which cuts off the view of the intermediate houses, trees, ships, or other objects. It is not to be expected that persons who do not take these things into the account should be enabled by practice to judge correctly of considerable distances at sea. Short distances may on most occasions be estimated by practised observers with sufficient accuracy for general purposes; but as the correctness of the judgment or opinion of an individual may always be questioned, the usual mode of judging or guessing distances at sea should not be allowed in a trial of the sailing qualities of ships, where accuracy and certainty are so very desirable. Nothing of the kind would be tolerated in a horse-race; and surely such a fallacious way of arriving at a conclusion respecting the relative characters of ships should not be adhered to if a better can be followed.

To manifest the propriety of making due allowance for the advantage which one ship may seem to have obtained over another by a shift of wind during a trial of sailing, it is only necessary to observe, that if two ships, A and B, which sail equally well, are close hauled, with the wind, for example, at east, A being five miles to windward of B; if the wind changes from east to north, A will appear to have lost five miles to windward, when, in fact, both have sailed equally well. This would be the case whether the wind changed suddenly, or very gradually. The writer does not suppose that when so great a change takes place at 90°, in the direction of the wind, some allowance is not in general made by naval officers for such an occurrence; but he is disposed to believe, when less palpable changes happen, they are frequently either altogether disregarded, or their effects on the apparent performances of rival ships are not duly appreciated. If the following suggestions were to be attended to in a future trial of the sailing qualities of a number of ships, it is believed the relative excellence of the vessels would be most clearly and satisfactorily ascertained.

Usually, in a sailing match, the vessels close in a certain order at the commencement of a trial. Each vessel has then a fair opportunity of measuring with trigonometrical accuracy the distance of the nearest ship; and can also observe with precision the bearings of all the ships. Every ship should do this at the same time, and should afterward keep a minute and exact account of her own rate of sailing, and of the direction of her course. The bearings of all the ships should be taken, and the distance of the nearest measured, at certain given periods during the trial, by every ship. Each of the ships should also note particularly the time at which a change of wind is observed to happen, and at the same instant should observe the bearings of all the others, and measure the distance of the nearest. The same should be done whenever the ships tack, or when they purposely alter the direction of their course, and also at the time of the termination of the trial.

Such an account of every trial should be furnished by each ship at the end of the cruise; and a good draughtsman should be employed to make a chart or drawing of the courses of the ships on each trial, first placing them in their relative positions at starting, and then tracing the course of each ship from her starting-point, according to the statements given of her course and rate of sailing. A moment's reflection will make it quite evident that, by having the bearings of each ship observed by all the rest, and the distance of the nearest, determined by each, at the same instant, any slight inaccuracy in an observation made on board one ship would be immediately discovered and rectified by the concurrence of the observations made on board the others. The bearings of any number of objects can be most accurately observed in a very short time, however distant they may be; and the distance of the nearest ship can be measured with much greater certainty than that of the more remote. The intersections of the bearings of the several ships, being found to accord with the measured distances of the nearest, determined by each ship respectively, will always fix the positions of the ships with the utmost precision. This method will also prove how nearly the rate of sailing had been correctly found and reported by each; and whether the ships had measured with exactness the distance of the nearest in every instance. A perfect chart of each trial could thus be made; and if this were to be done in a future experimental cruise, it would be unnecessary to ask any one which ship sailed the best. The charts would show which had sailed the fastest, which faster than another, and in what degree; and an opinion about the matter would be altogether superfluous and inadmissible.

The very great importance of accurately ascertaining the characters of ships as slow or fast sailers, appears from the consideration that it is impossible we can assign the best proportion between the length and breadth of a ship, until we become possessed of this knowledge. We have, it is true, some facts upon which we feel justified in grounding an opinion on this subject; but we have nothing sufficiently well ascertained and attested, to satisfy us it is impossible the conclusion we have been brought to, that our ships in general ought to be considerably broader than they are, can be wrong. An instance of this almost satisfactory kind of evidence, that our ships of war ought to be broader, has been furnished by the recent trial of sailing between the Winchester, a fifty-two gun frigate, and the Barham, a cut-down seventy-four. The Winchester appears to have established for herself the character of a very fast sailing ship, and there seems to have been no want of proof that the Barham sailed much better after she had been cut down than she did before. It was therefore to be expected that these ships would not be found to sail very unequally. And from the short trial which took place, it appears to have been found, the two ships sailed so nearly alike when by the wind, that it could not be asserted one was superior to the other; and in sailing with the wind abaft the beam, the Winchester was rather the faster sailer of the two.

The lengths of these ships, and their sailing draughts of water, are very nearly the same; but their breadths, and the weights of their hulls, and the forms of their bottoms, are very different. The Winchester is 173 feet long, 43 feet 9 inches broad, and her mean draught of water is 20 feet. The weight of her hull is about 1,000 tons; and the form of her bottom is defined by a very rising floor, a tolerably large area of floatation, a pretty sharp after body, and a rather unusually fine fore body. The Barham is 176 feet long, 47 feet 6 inches broad; her mean draught of water is 20 feet 3½ inches. The weight of her hull is about 1,420 tons; and the form of her bottom is defined by a flat floor, a rather less area of floatation, in proportion to her breadth, than the Winchester, and greater fulness of the fore body. The quantity of sail carried by these two ships is very nearly the same; and the angle of bracing the yards cannot be very different. The Winchester being the narrowest ship, has probably (though it is neither proper nor unavoidable that a comparatively narrow ship should have) a slight advantage in this respect.

The great and palpable differences between these ships are in their breadths, the weights of their hulls, and the forms of their bottoms. The greater weight of the Barham's hull (which is owing to her having been originally a two-decked ship), and her consequently greater displacement, must have operated as a considerable drawback to her velocity in sailing; and the form of her bottom, being that which was adopted first by the French, on the erroneous supposition that a flat deep floor gives great stability, and which form has been copied from the French by the constructors of the British navy, who have doubtless supposed it the *ne plus ultra* of excellence, is that which all constructors of ships, whether scientific or unscientific, appear now to consider and to have abandoned as the worst calculated for fast sailing. Whence then does it arise that the Barham is as fast, or nearly as fast, a sailing ship as the Winchester? Every difference between them, except that of the breadth, which can be supposed to affect their sailing qualities, must have been prejudicial to the Barham. To what then can the good sailing of the latter, in comparison with the Winchester, be attributed so much as to her being nearly four feet broader, and to her having an area of floatation greater by about 400 feet than that of the Winchester, and to her possessing in consequence a greater degree of stability?

Another reason why the Barham, a ship so much heavier than the Winchester, was moved as fast, or nearly as fast, through the water by the same quantity of sail is, that the fulness of the fore body, and the fineness of the after body, were greater in the Barham than in the Winchester; so that the advantage which the latter had over the former in the form of her bottom by the rise of her floor, was, in all probability, nullified by the disadvantage of her fore body being less full than it ought to be, and her after body less fine. The importance of a due degree of fulness to the fore body, and fineness to the after body of a ship, may be strikingly manifested by a comparison of the Winchester with the Java, another 52-gun frigate, of very nearly the same length, breadth, depth, and displacement.

The Java is known to be a decidedly bad ship. It has been stated by those who sailed in her, that in a sea at all rough she labours extremely, in comparison with other ships, and pitches with the utmost violence. The sole difference between the Java and the Winchester is in the relative fulness of their fore and after bodies. The Java is considerably finer forward and fuller abaft than the Winchester: in other words, the centre of gravity of displacement in the former is farther aft than the same point in the latter. And the consequence is, that although the ballast may be placed very far aft, which it must be in the Java, to bring her to the best sailing trim; yet the momentum of the weights at the bow being as great as in a ship with a full fore body, and there being so inadequate a support for those weights at the great distance at which they are situate afore the centre of gravity of the ship, they must act with immense mechanical advantage to augment the force of the pitching motion. The pitching of such a ship as the Java must necessarily be most violent and prejudicial to her sailing; and several of our ships of war are, unfortunately, such ships.

It is much to be regretted that this ship, which in the course of the repair she has been for some time past receiving, might, at a very trifling expense, have been made almost a *fac-simile* of the Winchester, and possibly even a better ship;—for the latter, as was above intimated, has rather too fine a fore body,—has been repaired so as to preserve all her old well-known bad qualities, and will, of course, be always just as laboursome and slow-sailing a ship as she ever has been.

A comparison might be made between some other ships which would lead, it is believed, to the same conclusion as that which has been derived from comparing the Winchester and the Barham;—that an increase of the breadth of our ships of war would make them better sailers. Until the contrary shall have been proved by actual experiment, it must continue to be doubtful, whether our ships of war in general might not with great advantage to their sailing qualities be made so broad that they would have a sufficient degree of stability without the use of more than a very small portion of the usual quantity of ballast.

A brief reference may here be made to our men-of-war brigs. The 18-gun brigs have generally been considered, for their size, the finest class of our ships of war; and of all the ships of our navy, with the exception of the Columbine, these vessels have the greatest breadth in proportion to their length. The 10-gun brigs, on the contrary, have been characterized as one of the worst classes of our vessels of war: and as these brigs are very similar in form to those of 18 guns, and are much narrower in proportion to their length, their acknowledged inferiority can be ascribed to nothing so much as to their want of greater breadth. The 10-gun brigs are 3,67 times as long as they are broad, whilst those of 18 guns are in length only 3,27 times their breadth. As it is a perfectly well-established principle in naval architecture, that a small ship should be broader, in proportion to her length, than a large one; if the brigs of 18 guns are not too broad, those of 10 guns are much too narrow.

It is only by experiment the best proportion between the length, breadth, and depth of a ship can be ascertained. It is, therefore, highly desirable that a few ships, of different classes, of great breadth, should be built; and their good or bad qualities as ships of war submitted to the most rigid and scientific scrutiny. A brig or a corvette might be in length just three times her breadth; the length of a frigate might be 3¼ times her breadth; and a ship of the line 3½ times. Ships built with these proportions of length and breadth, with the centre of gravity of displacement sufficiently far forward, could not but be good ships; and if they were to be made of that form, which, in Art. 32 of the last Number of this work, was shown to be the best adapted both for velocity and stability, it is in the highest degree probable they would be very decidedly superior to any ships which have yet been built.

ART. IV.—*Notice of a Pamphlet "On the Advantages of observing a Ship's Inclination at Sea, &c., by Henry Chatfield, of his Majesty's Dockyard at Plymouth, Member of the School of Naval Architecture."*

THIS little pamphlet contains many valuable observations on the present state of naval architecture, and its future improvement. No subject is more dependent on correct accounts of experience than this, and perhaps in none are the registered accounts of experience so vaguely expressed. The principal cause of the little improvement in the design of ships is the want of the union of mathematical and experimental knowledge. It is too much the practice to consider theory and experience as opposed to each other; and while the importance of the latter is universally admitted, the advantage of the other is too frequently neglected. We would not extol the benefits of theoretical knowledge by lowering the utility of experimental knowledge; much less would we prefer the isolated observations of experience, and such they must be without the connexion science alone can give them, to the certain rules of theory, founded on the known laws of nature. The combination of theoretical and experimental knowledge is necessary for the improvement of the design of ships.

If this be allowed, the question arises—In what manner can this combination of knowledge be obtained? Theoretical knowledge requires an education in mathematical science and natural philosophy, to be obtained only by an undivided attention to it for many years. Such observations on the qualities and behaviour of ships, as are necessary to constitute an experience useful in design, can be obtained only by a long service at sea. The attainment of these two kinds of knowledge in the same person, by his own application and observation, is incompatible: each requires a long experience, and each must be obtained by a different process. The necessary acquaintance with mathematical knowledge and natural philosophy may be obtained by any man of ability and application devoted to the pursuit; but the necessary knowledge to be derived from observation, requires an experience at sea in many classes of ships under various circumstances: this experience must be the result of the observations of many. The legitimate use of this knowledge obtained by observation is its being subjected to examination and comparison, according to the known laws of mathematical science. The only practical means of rendering this combination of knowledge applicable to the improvement of naval architecture, appears to be by collecting together the reports of naval officers on the qualities and behaviour of ships under all circumstances at sea, for the use of the naval architect. In this manner experimental and theoretical knowledge may be combined with complete advantage.

To render the reports of naval officers on the qualities and behaviour of their ships as useful as they are capable of being made, it is necessary that the information they contain should be clear and definite. Mr. Chatfield, in his pamphlet, particularly insists on the necessity of this correct method of stating the results of naval observations. He observes, "Questions which are to be made applicable to science should convey our ideas in definite terms, and in order to effect this, we must adopt legitimate language. Speaking of rotatory movements, for instance, the appropriate term is degrees; distances should be expressed by linear measurement; and intervals by divisions of time, &c."

Mr. Chatfield shows the great importance of having the inclination of a ship, under different circumstances at sea, correctly observed and registered, by means of a nauropometer, an instrument made for this purpose. The proper degree of stability of ships to be designed, and their correct masting, as well as the alteration of the stability of ships already built, by means of stowage, and of their masting, depend on such observations. He remarks, with justice, the little advantage which can be derived from such terms as "crank—stiff—well—pretty well," &c., in answer to the question, "How does a ship stand under her canvas?" and of "low—rather low—

very low," &c., to the question, "How does she carry her lee-ports?" and of "deeply—quickly—easily," &c., to the question, "How does she roll?" The terms are vague, and almost useless for the purpose for which they are intended; instead of the answers being expressed by measurement—by the number of degrees through which the ship inclines, they merely give a general notion of the ship's behaviour, dependent entirely on the opinion of the officers, and the arbitrary meaning they may attach to the terms they apply.

Mr. Chatfield's pamphlet contains some valuable remarks on the necessity of knowing the inclination of a ship under different circumstances, in order to point the guns correctly. He observes, "To explain the application of these remarks, let the inclination under different conditions of weather be carefully registered, noting the quantity of sail set in all cases; and let experiments be made on the effects produced by shortening sail in discretionary proportions; such proportions, for instance, as would be likely to take place according to the circumstances under which it might be deemed expedient to engage an enemy. The inclination of a ship under a given quantity of sail will of course vary according to the strength of the wind; consequently, the number of degrees that a vessel will right herself by taking in certain sails, will vary in a similar proportion, which must be tabulated with great care. The rate of sailing will also vary, which should likewise be noted, and the whole inserted in a table of the following description:—

Ship's inclination.	Sails set.	Rate of sailing.	Remarks on the weather.
—°	Courses, topsails, top-gallant sails, jib, f. topmast staysails, spanker.	— knots.	
—°	Courses hauled up.	— knots.	
—°	Top-gallant sails struck.	— knots.	

The above experimental table is the result of observations made on board the ———, between dates ——— and ———, on a voyage to and from ———. The vessel was stored and provisioned for —— months.

Captain.
Master.

"If trials of this kind were carefully conducted, it is evident that whenever a ship was under sail, and an engagement contemplated, nothing could be more simple than to observe the ship's inclination; and then, by referring to the recorded properties, ascertain the effects that would be produced by trimming the sails in any desired manner. This may be done at any period before the time of action, so that there need be no hurry or confusion on the part of the individual on whom it devolved, to direct the adjustment of the guns, nor on the part of the men at their stations. A very small table of results, made out on a few (about three) occasions, when the strength of the wind produced a sensibly different effect on the ship's inclination, might be placed near the nauropometer, from which it would be immediately seen to what angle the ship would be depressed in the cases of hauling up the courses, striking top-gallant sails, &c.

"Having ascertained this point, it only remains to elevate or depress the entire of the guns, through exactly the same angle, and fix upon the distance at which it is intended to commence firing; the sight may then be adjusted accordingly, and aim taken by its use; or, as many degrees may be added to or deducted from the ship's inclination, as are *due to the distance* of the object fired at, unless the distance is to be left to circumstances."

Mr. Chatfield proposes a new "coin on geometrical principles, to elevate or depress the guns with perfect accuracy, through every degree within the prescribed vertical range."

The pamphlet concludes with observations on naval construction, in which is shown the advantage which might be expected to arise from an "office of construction." We have long intended to offer some remarks on this subject, which we shall now briefly allude to, and resume at a future opportunity. The education necessary for the qualification of a naval architect is different from that which is necessary for a practical builder. The education of a practical builder requires a considerable acquaintance with mechanical and chemical science; of the former, to proportion correctly the strength of materials to the strain to which they will be subjected, and to apply the fastenings in the best manner to sustain the action of the forces to which they are opposed, so that a sufficient strength may be afforded to the fabric with the least expenditure of materials; and of the latter, to avoid bringing into chemical action substances which contact might render destructive to their durability. We would not confine within too narrow limits the education of the practical builder—the strains to which ships are exposed are, in some cases, difficult to estimate; but experience, derived from the examination of ships come home, after having been long at sea, and exposed to severe gales, will greatly assist the practical builder, in determining what parts require additional strength, which his mechanical knowledge may supply. The naval architect requires a much more extensive acquaintance with mathematical science and natural philosophy;—he needs a life devoted to the design of ships, to which all his pursuits should be directed. The experience of building and repairing ships does not prepare a man for the design of ships: the pursuits are widely different, and the previous education and habits should be in accordance with those objects.

The office of construction would concentrate all the information which could be obtained on naval design; it would collect the reports of naval officers on the qualities and behaviour of their ships, as well as the results of all experiments made in this and other countries connected with naval design. A perfect acquaintance with the different systems of design used in other countries should be possessed by the members of this office, in addition to a competent knowledge of mathematical science and natural philosophy. A most important duty which would devolve on this office would be the formation of a complete digest* of the elements of the ships of the British navy, and of all other ships of which the drawings and the reports of their qualities could be obtained.

If at one period more than another such an office of construction might be expected to be advantageous to the interests of naval architecture in this country, it is at the present, in which a new system of naval construction opens on us,—the use of steam-vessels in naval warfare. There is comparatively but little known on this subject; and it is to be expected that the next war will require a great change in the system of naval construction, to meet the exigencies of new circumstances. Mr. Chatfield observes on this subject, "There is not sufficient analogy between a sailing man-of-war and a steam-vessel, intended for the same service, to class them as bodies whose elements are determinable by the same laws and principles; experience in the one can hardly be called experience in the other; and they are so dissimilar, that a naval architect, in other respects tolerably conversant with construction, might fall into serious errors in designing a steamship. Great attention must now be given to this subject, which opens a new and wide field for inquiry; otherwise it will always be attended with speculation, to go beyond what has been done before. Imitating is certainly a safe mode of proceeding; but it is more creditable, and in every sense more desirable, to be able to rely entirely on our own resources; and a naval nation, naturally aspiring to excellence, should never stop short of that degree of perfection which is obviously within reach."—"We are now certainly only beginning a system; it must, therefore, be our object to establish laws and fixed principles relatively to this branch of nautical science, to guide us through the difficulties that may hereafter attend a much more enlarged plan of building than we have yet tried."

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* See Mr. Major's proposal for making a digest of the ships of the Royal Navy, in the "Annals of Philosophy," November, 1825.

A just tribute is paid in this pamphlet to the talents and knowledge of Professor Inman, to whom this science is more indebted than will perhaps be generally known in the present age. He has divested it of all the speculation and mystery which many have in past years endeavoured to throw round it. He has placed it on the same footing as other departments of natural philosophy; and shown that improvement is only to be obtained by subjecting all the elements of naval design to the known laws of mechanics, and by examining the designs of ships by the reports made on their behaviour at sea. By comparing the calculated elements of ships in this manner, the alterations necessary to improve future designs are discovered; errors are corrected, and deficiencies supplied; and in accordance with the service for which particular ships are constructed, their improvement is gradually and certainly carried forward.

What has been so well begun by the Professor, under the liberal patronage and directions of Government, we trust will be successfully carried forward by the members of the School of Naval Architecture, who have been expressly educated by him for this object. We are naturally anxious to see the merits of this establishment brought to this test; and we are sanguine in our hopes, that the result will fully answer the object which is intended to be obtained, the improvement of the design of the ships of the Royal Navy.

ART. V.—*Notice of "Scales of the Displacements; and of the Areas of the Horizontal and Vertical Sections; and of the Areas of the external Surface of the several Classes of Ships composing the British Navy, &c., by William Parsons, of his Majesty's Dockyard, Portsmouth, Naval Architect, formerly a Student of the School of Naval Architecture."*

THE principal object of this work is "to point out the fallacy of the present method of ascertaining the register tonnage of ships, and to suggest another founded on correct principles."

That the present rule does not give the true tonnage, or the quantity of lading a ship can carry, has been long known; probably from its establishment; the opportunity it affords of defrauding the revenue, by constructing ships to carry more than their computed tonnage, has been repeatedly shown; and the effect this has had on the forms of merchant ships, by the sacrifice of good sailing properties to the capability of taking excessive ladings, has been found in numerous instances to be most injurious.

"The rule at present in use for computing the tonnage, as established by the 13th Geo. III. cap. 74, is this: 'The length shall be taken in a straight line along the rabbet of the keel of the ship, from the back of the main stern-post to a perpendicular line from the fore part of the main-stem under the bowsprit. The breadth shall be taken from the outside of the outside plank, in the broadest part of the ship, either above or below the main wales, exclusive of all manner of doubling planks that may be wrought upon the sides of the ship.' In cases where it may be necessary to ascertain the tonnage of vessels afloat, by 26th Geo. III. cap. 60, the length is to be taken as follows:—'Drop a plumb-line over the stern of the ship, and measure the distance between such line and the after part of the stern-post, at the load water-mark; then measure from the top of the said plumb-line in a parallel direction with the water, to a perpendicular point immediately over the load water-mark, at the fore part of the main-stem, subtracting from such admeasurement the above distance; the remainder will be the ship's extreme length, from which is to be deducted three inches for every foot of the load draught of water for the rake abaft.'

"Then by 13th Geo. III. cap. 74, and 26th Geo. III. cap. 60: 'From the length taken in either of the ways above-mentioned, subtract three-fifths of the breadth taken as above, the remainder is esteemed the just length of the keel to find the tonnage; then multiply this length by the breadth, and that product by half the breadth, and dividing by 94, the quotient is deemed the true contents of the lading.'"

Mr. Parsons gives several instances in which the fallacy of this rule is made strikingly apparent; and shows that even by calculating the tonnage of the same vessel by the two methods given above, the difference of the results is very considerable. He observes, that by "the draught of water being omitted in the rule, the practice of increasing the depth has become general, by which means the vessels are capable of carrying a greater burden without increasing the register tonnage." He says also, "The omission of the draught of water in the rule is considered as its only defect, such however is not the case; the principal defect is, that the form of the vessel is not taken into consideration. This error in the rule is carried to such an extent at the present time, that the register tonnage of merchant vessels is generally only two-thirds of the absolute burden. Now this excess depends wholly on the form, and therefore varies in almost every vessel, even of the same principal dimensions: and we have said, the present rule for tonnage is totally independent of the form of the vessel, this excess is wholly exempt from any dues levied by this rule; or if it be observed that the dues are laid on the apparent tonnage, with reference to this excess, the objection is not removed, as the excess is not constant."

The fallacy of this rule is clearly shown by the author of this work; it may however be observed, that when he states, "that the omission of the draught of water in the rule *is considered as its only defect*," he claims the exposure of its fallacy to a greater extent than can be allowed to him. This, with some other defects in the rule, particularly the method of obtaining the length for tonnage, are generally understood; it is acted on in the practice of building merchant ships in the instances he brings forward. Chapman observes, in the rule for tonnage proposed by him, to which we shall refer, "It is impossible to ascertain a ship's actual burden from the principal dimensions, that is, by the product derived from length, breadth, and depth; because two ships may be of an equal length, breadth, and depth, but greatly differing with regard to tonnage, *owing to the greater or less sharpness of the bottom*," &c.

Before we proceed with a description of the scales of tonnage in Mr. Parsons' book, we shall give some of the rules for calculating the tonnage of ships used in other nations, with some other rules proposed for this purpose.

The following is the French rule for measuring the tonnage of merchant ships:—"Add the length of the deck taken between the rabbets to that of the straight line of the keel, and take half their sum; multiply this quantity by the greatest breadth at the midship beam, and the product by the depth of hold and the height between the lower and upper decks, and divide the product by 94. If the vessel has only one deck, take the greatest length of the vessel, multiply it by the greatest breadth in midships, and the product by the greatest height, and then divide by 94."

This rule is simple, but very erroneous. It is true that a certain depth of the vessel is taken as the third dimension, but it is altogether distinct from the depth the vessel is immersed by the lading: the depth from the load to the light water-line. This depth may vary very considerably in two vessels whose lading may be equal: the one may be much deeper than the other by having a greater rise of floor, the total displacements of the two vessels being the same; the depth may also vary from the decks being placed at different heights in the two vessels. The different forms of body are also totally neglected in this method of measurement.

The following is the method of measuring the tonnage of merchant ships in the United States of America; 64th section of an act of Congress, approved 2nd March, 1799:—"That to ascertain the tonnage of any ship or vessel, the surveyor, or such other person as may be appointed by the collector of the district to measure the same, shall, if the said ship or vessel be double-decked, take the length thereof from the fore part of the main-stem, to the after part of the stern-post, above the upper deck, the breadth thereof at the broadest part above the main wales, half of which breadth shall be accounted the depth of such vessel; and shall then deduct from the length three-fifths of the breadth, multiply the remainder by the breadth, and the product by the depth, and shall divide this last product by 95, the quotient whereof shall be deemed the true contents or tonnage of such ship or vessel. And if such ship or vessel be single-decked, the said surveyor, or other person, shall take the length and breadth as above directed, in respect to a double-decked ship or vessel; shall deduct from the said length three-fifths of the breadth, and taking the depth from the under side of the deck-plank to the ceiling in the hold, shall multiply and divide as aforesaid; and the quotient shall be deemed the tonnage of such ship or vessel."

These rules appear to have been derived from the English and French rules: the first, for double-decked vessels, being nearly the same as the English, and the latter, for single-decked vessels, being nearly the same as the French. They respectively possess the inaccuracies of each, with the additional error of being inconsistent with each other.

The Swedish Government, in the year 1778, ordered the following rule for measuring a vessel's burden to be used:—

"1. All mensuration is to be done by the Swedish foot, and the vessel's burden to be marked down in lasts, each to be considered in weight equal to 18 skeppund, iron weight, or eighteen times 320lbs. Swedish. 2. The vessel's length to be measured on the highest water-line, when loaded, from the fore part of the rabbet of the stem to the aft part of the rabbet of the stern-post. 3. The ship's breadth is to be measured in midships without-board, close up to the main wale. 4. The height to be measured from the surface of the water without-board, up to that mark which determines how deeply the vessel will swim when completely loaded. 5. Multiply these three admeasurements by each other, and divide the product by 112, should the vessel be of the usual shape, and neither too full nor too sharp at the stem and stern: if the vessel is sharper, the divisor must then be greater: and if fuller a little less, as pointed out to the measurer in the separate instructions. 6. If the necessary provision, water, wood, and utensils, for the voyage should not be on board when the ship is measured, and which weight does not actually belong to the burden that the vessel is measured to carry, then it is necessary to deduct from the calculated burden of lasts as follows: on a vessel of 350 lasts is allowed 11 lasts deduction; (corresponding deductions are given for vessels decreasing in burden from 350 to 40 lasts;) and so on in proportion, in such vessels as are not coincident with the above denomination. But should any of the articles mentioned be on board, the deduction will be less in proportion. 7. Should one or more of the necessary cables not be on board when the vessel is measured, then the following deductions are to be made: for an 18-inch cable 25 skeppund, iron weight. (The deductions for smaller cables, down to a four-inch cable, are specified.) 8. Should one or more anchors be wanting, their weight is to be deducted in proportion to the vessel's size. 9. If the vessel's sails are not on board, the deduction from its number of lasts is to be as follows: on a vessel of 350 lasts, 14 skeppund, iron weight. (Corresponding deductions for the sails of smaller vessels, down to those of 40 lasts, are given.) And less in proportion when fewer sails are wanting. 10. If the vessel is built to carry guns constantly, and that none, or part of them only, are on board, then a deduction for cannon, carriages, gun-tackling, &c., is as follows: for a 12-pounder, with its requisites, 13 skeppund, iron weight (with corresponding deductions for smaller guns). 11. Should the vessel, when measured, have its ballast on board, then that weight must be ascertained, and added to the number of lasts found; but it is best to measure the vessel before it is ballasted, if convenient. 12. The ship's measurer having duly considered the foregoing circumstances, and in consequence thereof ascertained the vessel's proper tonnage to a certain depth, fore and aft, when loaded, he is then to make an entry of the foregoing in the book of admeasurements given him for that purpose, which book is run through and sealed with the seals of the Court of Aldermen and Custom-house: he is also to enter the number of lasts requisite to immerse the vessel, progressively, from one foot at the beginning of the loading till when completed, and also to set down how deep she lies fore-and-aft when unloaded. He is to deliver copies of the same, with specific calculations, admeasurements, and deductions of all this, to the Court of Aldermen and Board of Customs, within two days after measured, that the same may be examined and sanctioned. 13. Should there be anything to be observed by the parties, the same must be made known at the respective places, within eight days after the delivery, at the expiration of which time the ship's register will be made out, and the approved calculation of the measurer annexed to the same, and to be kept on board as the ship's inventory. The same is to be entered, with all the calculations, in bound paged books, and alphabets thereunto annexed, in the Court of Aldermen and at the Custom-house. 14. Whereas vessels, when old, and soaked through by the water, cannot carry so much as when new, it is therefore requisite to measure the vessel every tenth year, in like manner as expressed in the twelfth section."

In the instructions alluded to in the fifth section, vessels are supposed to be divided into seven classes, according to their fulness or sharpness; and corresponding divisors are given, which were obtained by calculations made on different vessels. These divisors vary for the whole depth immersed by the lading, from 104 for the fullest, to 122 for the sharpest vessel; and the divisors to be used near the load water-line vary from 98 to 104, and near the light water-line, or discharging line, from 108 to 133.

This rule is very good—strictly correct in principle; the only error which can arise in practice, in ascertaining the lading on board any vessel, is in the divisor being left to the determination of the measurer, dependent on his judgment and honesty. There can be no doubt, however, of a skilful measurer, by great practice, being able to determine the divisor with ease and certainty.

Mr. Parkin, late master shipwright of his Majesty's dockyard at Chatham, has given two rules for calculating the tonnage of ships, published in "The Shipwright's Vade Mecum:" the one for ships of the Royal Navy, and the other for merchant ships. The following is the rule he has proposed for merchant ships:—"1. Take the length of the lower deck, from the rabbet of the stem to the rabbet of the stern-post; then take $\frac{31}{32}$ of this length, and call it the *keel for tonnage.* 2. To the extreme breadth add the length of the lower deck; then take $\frac{3}{55}$ of this sum, and call it the *depth for tonnage.* 3. Set up this depth from the limber strake; and at that height, take a breadth also from out to outside of the plank at dead flat. Take another at two-thirds of this height, and another at one-third of the height. Add the extreme breadth and these three breadths together, and take one-fourth of the sum for the *breadth for tonnage.* 4. Multiply the length for tonnage by the depth for tonnage, and the product by the breadth for tonnage, and divide by 36,6666 or 36$\frac{2}{3}$, and the quotient will be the burden in tons."

This rule seems to have been formed with considerable labour, and it presents the appearance of a little approach towards the true measurement of the tonnage. It is not, however, founded on correct principles: the elements which enter into the measurement of the true tonnage or lading being given in certain proportions of other elements, which do not bear a constant ratio to them. For instance: for the depth between the light and load draughts of water, a certain proportion of the length and breadth is substituted. The examples given by Mr. Parkin show that the results of his rule come generally much nearer to the true lading than the present rule; but it can at best be considered only as the substitution of a less error for a greater.

In the year 1791, the Society in London for the Improvement of Naval Architecture, of which his present Majesty (then his Royal Highness the Duke of Clarence) was President, offered eight premiums for different objects connected with improvements in naval science, one of which was the following:—The Society offer a premium of twenty guineas and the silver medal for the most ready and accurate method, by approximation or otherwise, for determining the tonnage of vessels and ships of every description, from an admeasurement of all the principal dimensions.

The indefatigable and justly celebrated Chapman, who was an honorary member of the Society, sent a paper* on the subject which was published in the "Account of the Institution, &c. of the Society," printed in London in 1792.

Chapman gives two rules in this paper: the first is an approximate rule for tonnage, which he considers chiefly in connexion with the payment for the building of ships. He says, "The cost of a ship is nearly in proportion to its outer surface multiplied by the thickness of its sides; but as this thickness may be considered in proportion to one of the dimensions, so it may be judged that the product of length, breadth, and depth gives the proportional costs. Nevertheless, a difficulty attends this; namely, the length and breadth can precisely be fixed, but the height or depth not altogether so easily. For instance, if I use the depth of the hold as the third dimension, it may happen, in consequence of the cargo which the vessel is to carry, that the lower deck has been laid a foot higher or lower, although its length, breadth, and the whole of the height remain the same without any alteration; the expense of building equally the same, as also the burden; but the difference of the height of the deck increases or decreases the product, and consequently the price in proportion. In like manner it acts with regard to the upper deck. Should the height of the vessel from the keelson to the gunwale be taken as the third dimension, it will be found to vary as much as the former. For example, the gunwale might be made half a foot or a foot less in height, and that added to the gunwale after the ship is built, which of course would make it cost less than if that height was included in the calculation. If that part of a ship which is immersed when loaded should be taken as the third dimension, then would it depend on how high the water-line stands marked on the draught up to which the ship ought to be loaded, which might also be higher or lower. It is therefore better to institute a rule which, although not totally exact, is still determined, and not subject to disputes or confusion.

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* The Swedish rule given above is taken from this paper.

"I shall therefore propose, that the ship's height or depth should be taken in a proportion to the two precise or determined dimensions, namely, as the square root of the product of the length and breadth. If now the length and breadth be expressed by L and B, then must the depth be in a certain proportion to $\overline{LB}^{\frac{1}{2}}$ without regarding how great that quantity may be. This ought to be multiplied by the length and breadth; that is, the number of tons shall be as $\overline{LB}^{\frac{1}{2}} \times BL = \overline{LB}^{\frac{3}{2}}$. This expression is a solidity or content which characterises the size of the ship, in which two of the principal dimensions are equally involved. To make practical use of this expression for the purpose of determining a ship's burden in tons, and at the same time that it sometimes agrees with the old method, it will be necessary to find what proportion the breadth bears to the length, agreeably to the old method of determining the tonnage when the contract has been equally beneficial. Suppose the breadth to have been $\frac{53}{200}$ of the length, or the length to be 100 feet when the breadth is $26\frac{1}{2}$ feet. According to the old method:—

$$\frac{\overline{100 - \frac{29}{40} \times 26{,}5} \times \frac{\overline{26{,}5}^{2}}{2}}{94} = 301{,}78 \text{ tons: therefore}$$

$$\frac{\overline{100 \times 26{,}5}^{\frac{3}{2}}}{x} = 301{,}78;$$ where $x = 452$. In consequence

of which the size of the ship in tons always ought to be expressed by $\frac{\overline{L\,B}^{\frac{3}{2}}}{452}$."

This divisor, 452, is subject to the alteration according to circumstances.

The other rule given by Chapman, is for the correct determination of the weight of the lading which a ship carries. This rule is similar to that given by the Swedish Government, except that Chapman adapts his divisors to the English ton, instead of the Swedish skippund. He gives a table for ten classes of vessels according to the fulness or sharpness of their bodies, in which the divisors vary from 39 in the fullest, to 48 in the sharpest vessel. He takes the extreme length on the load water-line, L; the extreme breadth just below the main-wale, B; and the mean depth between the light and load water-line; the product of these three dimensions, divided by D, the variable divisor in his table, gives the lading in tons.

This rule is also strictly correct in principle; but has the same error in practice as that of the Swedish Government given above; the determination of the divisor at the discretion of the measurer.

A rule for the measurement of tonnage is given at page 163, vol. i., of this work, in which a near approximation to the true weight of lading is obtained, by multiplying together the length of the load water-line between the fore part of the rabbet of the stem and the after part of the rabbet of the stern-post, the greatest breadth, and the mean depth between the light and load water-lines; taking three-fourths of the product, and dividing by 35. To this sum is added an allowance in proportion to the fulness of different bodies, determined by actual measurement.

In the Shipwrights' Repository the error of the present rule of tonnage is clearly explained, and the true tonnage is shown to be the difference between the total weight of the ship to the load water-line, and the weight of the hull and furniture. The author appears to have understood this subject, although he connects with it some erroneous observations, and has not taken the easiest method of obtaining his results. He gives several examples of the tonnage of ships: the following is the result of his calculations on the tonnage of an eighty-gun ship:—

	Tons.	lbs.
Weight of the ship at her launching draught of water ...	1593	406
Weight of the furniture	195	720
Weight of the ship at her light water-mark	1788	1126
Weight of the ship at her load water-mark	3554	356
From which deduct the weight at light water-mark	1788	1126
Real burden	1765	1470

	Tons.	lbs.
Burden in tons by common rule	1959	929
Real burden	1765	1470
	193	1699

The real burden of this ship is therefore 193 tons less than her computed tonnage. In an East Indiaman, his result shows that the real burden was 178 tons more than her computed tonnage. In his other examples the differences are still greater.

We shall now proceed to describe the scales of tonnage given by Mr. Parsons, and shall then conclude by some observations on the present state of the subject. Chapman, Clairbosi, Atwood, and others, have calculated and drawn scales of tonnage for particular ships; but Mr. Parsons has by very considerable labour, and with great care and correctness, made the calculations and drawn the scales of tonnage for most of the classes of ships of his Majesty's navy, and for twenty-one classes of vessels of the British mercantile navy.

The scales of tonnage are drawn for all the vessels from the keel to the gunwale: each vessel is divided into two parts, the fore and after bodies, by a vertical line at the middle of the length of the load water-line, between the fore side of the rabbet of the stem and the aft side of the rabbet of the stern-post; and a separate line of tonnage is drawn for each body. The solid content of the body in cubic feet, at different heights, is calculated by sections parallel to the keel, which being divided by 35, the number of cubic feet of sea-water in a ton, gives the weight of water which would be displaced at those heights. By setting off from a vertical line on lines parallel to the keel these results by a scale of tons, spots are obtained, through which the line of tonnage is drawn. By setting up any height on the vertical scale of feet, and drawing a horizontal line at that height, this line represents the weight of the corresponding displacement, which is found by transferring it to a scale of tons placed horizontally over the figure. By taking the heights of the light and load water-lines of any vessel, and transferring them in this manner to the scales of tonnage, their difference gives the weight of the displacement between the light and load water-lines, or the true weight of lading. The mean depths are taken for each body separately, and the sum of the two parts thus found gives the total tonnage.

"By these lines of tonnage may be ascertained the weight put on board, or taken out of the vessel at any time, by observing the different draughts of water, and measuring the tonnage or weights corresponding to them; the difference between these weights will be the quantity put into or taken out of the vessel. For example, in the cutter of 160 tons, when ready for sea with all stores in, the* draught of water is 8 feet 9 inches forward, and 13 feet 6 inches aft, the mean of these is 11 feet 1½ inches; and 12 feet 3¾ inches is the mean depth for the after body, which gives 93 tons for the weight of the after body. The mean depth for the fore body is 9 feet 11¼ inches, which gives 83 tons for the weight of that body, therefore the whole displacement is 176 tons; but the weight of the hull when launched was 82 tons, consequently the difference on the weight put on board must be 94 tons.

"This method of taking the mean depth in each body is the most correct, but will seldom be necessary; as if the mean depth of the extremities is used alone for each body, it will give nearly the same result." The tonnage is then measured by taking the mean depths of each body separately, and the difference of the results of the two methods is found to be only one ton. In vessels with a less difference of draught of water, the error is proportionally smaller. On this account the mean depths of the load and light draughts of water are used in the scales of tonnage; which "is in fact supposing the vessel to swim on an even keel, at the mean draught of water in each case."

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* In this quotation the references to the scales are omitted. In Art. 14, vol. iii., of "Papers on Naval Architecture," an example is given from Mr. Parsons's previous pamphlet on this subject, in which a figure and the references are inserted.

In considering the practical benefit of the scales of tonnage, it is necessary to examine the difficulties which would attend their use. The principle of this method of measuring the tonnage of ships is strictly correct, assuming that the light and load draughts of water are determined; but in the determination of these lines appears the practical difficulty. Mr. Parsons has assumed the launching draught of water as the light draught: this is the easiest method, but not the most correct. We are considering the application of these scales of tonnage to merchant ships; with respect to their application to the ships of the Royal Navy, little need be said. The tonnage should express the lading which can be put into a ship, when every necessary article of furniture and stores is on board, to bring it down to its load draught of water. The two Swedish methods given above, one of which is in use in Sweden, removes this difficulty, by taking the light draught of water, under the necessary circumstances of having everything on board except the lading; an established allowance being made for every article not on board at the time. We recommend Mr. Parsons to adopt the same plan: we admit that it will be attended with considerable trouble, in obtaining the weights of the different furniture and stores; but it is the only method of obtaining the correct light draught of water, which is the first circumstance to be known in measuring a ship's tonnage. The next difficulty, and by far the greatest, is the determination of the load draught of water. Two methods suggest themselves of removing this difficulty. The load draught of water of a ship may be determined by officers appointed for this purpose immediately a ship is built, and inserted in the register, by which draught of water the tonnage may be measured. The objections to this method are, the liability of the load draught of water being incorrectly determined at first, either fraudulently or ignorantly, needing alterations afterwards; and the capability it affords the owner of taking on board, at his own risk, a greater lading than that for which his ship was registered. Experience may, however, render the officers capable of ascertaining the load draught of water with considerable accuracy, and fines may deter the owner from incurring the risk of loading his ship deeper than it was constructed to swim with safety. Another method of obviating this difficulty is by a ship's always paying duty on the quantity of lading on board; so that the measurement of tonnage may be taken to the actual draught of water at which the ship swims when it comes into port. This would render the load water-line at first determined little more than nominal: it would allow a vessel's being spoken of as of a nominal tonnage, which would produce no error in the measurement of the real tonnage on board. Either of the above methods may render these scales of tonnage applicable to general use; we prefer the latter, because it carries the correct principle of measuring the true lading fully into practice.

Different methods of approximation have been proposed, by taking the girths of the body, &c.; but as all these are defective in the true principle on which the tonnage can alone be correctly measured, their adoption would be attended with very little benefit. If the true principle of measuring the weight of lading be not adopted, we consider that the change of the present rule for another would be unnecessary: it would be at best but the substitution of one error for another. Methods of determining the quantity of lading have been given, in relation to the space occupied by it, without reference to its weight. The difficulties of rendering such methods generally applicable to the measurements of ships' ladings, are greater than those connected with the present method of determining the weight of the lading.

It is probable that tables of tonnage may be preferred by many to scales of tonnage; but as their principle and use would be the same, the preference is indifferent. It may also be observed, that if the whole displacement were represented by one scale, instead of being divided into two parts for the fore and after bodies, the use of these scales would be more simple in their application to the tonnage of ships, although less useful for general purposes of design.

The above observations are not intended to refer to the application of this method of measuring the lading a vessel carries, to the payment for building. A separate* rule for this purpose might be adopted, founded on the dimensions, scantlings, &c., of the ship. Mr. Parsons observes, that his scales of the exterior surfaces might be used for this purpose: this surface, multiplied by the mean thickness of the ship's side, would give a tolerably correct measurement of the quantity of materials. "As the expense of building vessels must be in proportion to their outside surfaces, these lines will be a much better criterion for estimating the expense than the register tonnage."

In this valuable work of Mr. Parsons, the principle on which the correct tonnage of ships depends is clearly explained, and the method of its general application shown. The whole of the scales and elements will be found generally serviceable to the naval architect in the design of ships.

ART. VI.—*A New Method of constructing Beds and Coins for Naval Guns.* By MR. HENRY CHATFIELD, of his Majesty's Dockyard, Plymouth; formerly of the School of Naval Architecture.

A BED and coin being a mechanical contrivance for supporting the breech of a gun, it may be proper, before we enter into the particulars of their construction, to observe that the vertical evolutions of naval guns are confined within the limits of sixteen degrees, viz., an elevation of *nine* degrees and a depression of *seven*, when mounted on the common carriage. This being the prescribed range recently established as a guide for determining the size of ships' ports, we may regard it as a correct criterion in constructing beds and coins: but it should be understood, that when we speak of guns not being elevated more than nine degrees, it is signified that that is the greatest angle at which the piece will recoil,* without striking the portsill.

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* See Chapman's first rule.

One indispensable property which the bed and coin ought to possess, is the power of affording support to a gun at *every* point within the sixteen degrees; for unless this can be effected with certainty, the efficiency of a battery will be proportionably destroyed.

The present practice of constructing beds and coins is so defective in principle, that there is often a total absence of support to the breech of a gun sometimes to the extent of *three* degrees out of the sixteen; yet, although so obvious a defect could not fail of being frequently remarked, it does not appear that any adequate plan has been devised to correct so great an imperfection in the armament of the British navy. The interruption of support is dependent on two causes: first, The method of changing the position of the *bed* when it becomes necessary to alter its situation, in order to give more elevation to the gun than the *thinnest* part of the coin will afford; and secondly, From the coin itself not being formed on a principle of giving *continuous* support to a gun, when changed from lying flatways to being placed upon its edge. These are great and avowed deficiencies; but they have recently been modified in some measure, by supplying every gun with an additional hand-coin, similar to those used for carronades.

When a want of support occurs in actual service, so that a gun cannot be directed with precision, the coin is usually placed between the gun and the cheeks (or brackets) of the carriage to keep the breech up to its required height; but a practice of this kind is objectionable for many reasons, and can only be sanctioned as an expedient. Nothing can justify a defective system, unless it be unavoidably bad; and it is not because a naval engagement generally takes place under this or that condition, and rarely under other circumstances, that the bed and coin should be suffered to continue capable of giving partial support only to the breech of a gun. If we tolerate imperfections which may prevent a gun being adjusted to any *possible* elevation or depression (within the limits of sixteen degrees), we incur the responsibility of speculating with our national interests and honour, and of unfairly disappointing those who fight our battles.

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* Perhaps it would be better if ships' portsills were cut parallel to the *round of the beam*, or to the direction in which the gun recedes, instead of being trimmed level, or very nearly so. This would make a difference of about a degree each way, where the ship's side is of large scantling.

Precision in naval gunnery is as important as precision in anything else; and it will be seen by the following narrative, that where men are properly disciplined in the exercise of their guns, *theoretical inaccuracy is a practical evil;* and that the unscientific construction even of so simple a machine as a coin, may prove to be a serious defect in system, and of some moment in actual warfare.

The biographer* of the Hon. Captain Duncan,† after enumerating the many naval services of this gallant officer, observes as follows:—"There is another point which Captain Duncan has great reason to pride himself upon; namely, his attention to naval gunnery, and a recital of the circumstance which we are told first led him to see the necessity of attending thereto, may be a useful lesson to our young officers.

"A few weeks after the Porcupine (24 guns) was manned, Captain Duncan chased a ship during the night in the Archipelago, which proved to be an American merchant vessel. While hailing her, and while the two ships were almost touching each other, a gun on board the Porcupine went off by accident, and a whole broadside followed. The guns were all double-shotted, and Captain Duncan naturally supposed the neutral ship would be cut to pieces. Although happy to hear she had not suffered, his surprise was very great to find that a broadside could be fired so close without producing any effect: from that moment, he saw the absurdity of the common form of exercise which he had been accustomed to pay so much attention to as is generally done; and that real exercise, and the greatest and most constant attention to it, was necessary.

"In a short time the crew of the Porcupine became perfect gunners; the Mercury's were the same; and never, during the war, did the firing of any ship surpass that of the Imperieuse.

"One day under a battery, the captain of a gun was asked by an officer, why he did not fire? The man replied, The *coin edgeways is too much and not enough put flat;* I am chipping a bit of wood for it."

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* Marshall's Naval Biography.

† The present Storekeeper-General of the Ordnance.

What could be more applicable to the subject of the present article than this anecdote? It shows the necessity of paying minute attention to what are sometimes called points of theory, but which are, in reality, broad principles in practice; and while it establishes the fact, that the support commonly given to the breech of a gun is uncertain and irregular, owing to the unscientific construction of the beds and coins, it excites one's surprise that the hint it offers has not led to the introduction of an efficient system long ago.

Before we proceed to describe the proposed method of constructing beds and coins, let us briefly consider what it is that determines the elevation and depression of naval ordnance.

The elevation of a gun at sea depends on two considerations, namely, the distance of the object to be fired at, and the lateral position of the ship.

If an object be within 400 yards, a 24-pounder gun will carry a ball to strike it when the axis of the piece is horizontal; in such a case, therefore, it would be necessary to elevate or depress a gun on board a vessel, though exactly the same angle as that to which the vessel is inclined, in order to ensure horizontal firing.

This is too evident a principle to need demonstration; and it is one which may easily be acted upon by placing a pendulum (connected with a graduated arc) in conspicuous parts of a ship to denote the angle to which the vessel heels.

But if the distance of an object exceed 400 yards (the assumed point-blank range), the gun shonld be elevated *one* degree for about every additional three hundred yards, and the number of degrees due to the whole distance should be added to, or deducted from, the inclination of the ship, according as the enemy is to leeward or windward.

As the *distance* of an object and the *inclined position* of the ship from which a gun is fired alone govern the vertical evolutions of a piece of ordnance, it remains to inquire whether a ship often undergoes any rapid change of lateral position, and whether those changes are subject to a law of variation which is understood.

It is important that we should dwell a little upon this point, because the inclination of a ship is the *variable* part of the conditions of firing within point-blank range, or at a given distance, and therefore involves a most essential question in marine gunnery; and further, because it has been asserted upon high authority, that "it is not of any material importance whether the coin be adjusted or not; neither can any disappointment arise from any alteration that may take place in the position of the coin in firing."

With deference to this opinion, it is submitted that nothing can be worse than a series of guns so inmethodically supported at the breech, that if the whole were discharged simultaneously, no two of them would carry a shot the same horizontal distance: or, if the rolling of the ship be made the means of giving the proper elevation of the guns, no two of them could be fired at the same instant.

When a vessel rolls through a given arc, the successive degrees are performed in unequal intervals of time, the motion not being uniform; and the action of rolling is so far analogous to the vibrations of a pendulum, that the velocity may be considered greatest in the middle of the arc, and least towards the extremities. It is obvious too, that at the extremes of oscillation, there is a temporary suspension of motion, varying in duration according to external circumstances. Now, this variation of velocity is far from being a mere theoretical difference, adduced for the sake of refining the argument or supporting a particular opinion; but it is an essential and practical alteration of velocity which is sensibly felt on board every ship, and may be as certainly calculated upon as the return of the ship to any of her former positions. This being the case, it follows that if it were intended to adjust a gun upon the plan of "watching the opportunity of firing," the most correct system would be to study those positions of the ship which afford the best means of taking a deliberate aim; and, by the same rule, to avoid that position which is accompanied with the greatest rapidity and movement.

Admitting the truth of this argument, it *is* of "material importance" how the coin is adjusted. It is material as regards the facility of firing any gun taken separately; it is also material in point of *time* (in the aggregate), a slow motion par-taking more of the character of permanency than a comparatively quick movement; and it is material in the great object of rendering a battery uniformly and simultaneously destructive by the concurrent discharge of the artillery. There is another advantage too, in connexion with the judicious adjustment of a coin, which ought to be appreciated; and that is, the means it affords of giving the true pointing of the guns in *anticipation*, or before the object to be fired at meets the eye; which may be done without being able to see the horizon, and is as easily effected in a fog, in smoke, or in the dark, as at any other time.

It cannot for an instant be doubted, that there are many conditions under which we may encounter an adversary, when it would be a most important thing to be prepared for firing, by an approximate adjustment of the coin. In passing quickly under the stern of an enemy—in crossing his bows—in meeting him on opposite tacks—in coming up with him—in waiting his approach, &c., it is unquestionably of great consideration that no unnecessary delay take place. Now it is manifest, that if a ship be under sail (which she must be, to go through the supposed evolutions), she will be deflected from an upright position in proportion to the quantity of canvas she carries; and it is also evident, that the more sail she bears, the better will she be able to choose her situation, at the same time that she will be less liable to unsteadiness from the undulations of the sea. But the *direct* velocity of a ship requires proportional promptitude in firing, when passing an object of attack; if therefore the ship's inclination be carefully observed by an instrument on board for that purpose, it would furnish such information relative to the proper adjustment of the coin, that the utmost *precision* and *celerity* of firing would be ensured, at a moment when there may be but very little latitude for watching the roll of the ship. "It is this *instantaneous aim*," as Sir W. Congreve says, "that we are in search of for a naval sight."

Sir W. Congreve's sight is certainly a valuable invention, and will at any instant prove whether a gun is correctly pointed; but it is strange that the scientific general did not attach some importance to the adjustment of the coin, instead of trusting to the motion of the ship to give every gun, in turn, its true elevation. The intervals between the times of firing must, for this reason, become as varied as the positions of the coins are promiscuous; and the conditions of taking aim may be favourable, or they may not; but whichever way it may happen, it will be purely accidental. The coin should give the *level* of the gun, and the sight should give the *aim*. The coin would give the level with mathematical nicety, if the ship were quite steady; but as that cannot be the case in actual practice, it is, critically speaking, only an approximate operation to level the guns with the coins, and it therefore becomes necessary on that account to correct the deviations by the eye. Hence, "the importance of some instrument for securing the level* as well as the aim of naval ordnance:" and if both be made to co-operate, the art of marine gunnery will attain nearer to perfection than it possibly can so long as either consideration is neglected.

Having stated what I conceive should constitute the requisite properties of a bed and coin for naval guns, I shall recapitulate the argument by enumerating the qualities which the new beds and coins will be found to possess; and then describe the nature of their construction.

First. They will afford support to the gun at *every* point within the extreme angles of elevation and depression.

Secondly. They will regulate the *horizontal* firing, if the ship's inclination be given; and will also determine the proper pointing of a gun when the distance of an object exceeds point-blank range, provided the distance be known.

Thirdly. The *index* on the coin, and the *graduations* upon the bed, are arranged in such a manner that it is not possible to confound the angles of elevation with those of the depression, nor to mistake one angle for another.

Fourthly. Every sailor that knows one figure from another, may work a bed and coin on this principle without any difficulty whatever.

Fifthly. None of the properties of the common bed and coin are sacrificed for the sake of the advantages proposed by the new plan.

Sixthly. That if the practice of working guns upon this

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* Sir W. Congreve's Pamphlet, p. 22, note.

"system" were disregarded, the *first* advantage enumerated would nevertheless remain unaltered, and no practical evil whatever would result from inattention to the proposed method of regulating the pointing of the guns by the inclination of the ship.

Seventhly. That every evolution can be accurately and promptly performed with *one* coin only, and only one change in the position of the bed.

Eighthly. That the whole of the elevation being obtained when the bed is in its upper position, and the whole of the depression with the bed in its lower position, the proposed plan possesses a superiority over the common system in this respect; for the average elevation of a gun when resting upon the common bed being five degrees, if the inclination of the ship vary, sometimes exceeding five degrees, and sometimes less, the bed must be shifted accordingly.*

Method of constructing the proposed Bed and Coin.

Fig. 13, represents a gun and carriage, with the axis of the piece horizontal. Let a level line be drawn from the lowest point of the breech, extending to Figs. 14 and 15, as shown by a dotted line. In Fig. 14, draw *a b* parallel to the dotted line, 2½ inches† below it, and 3 feet long. Bisect *a b* in *c*, and draw lines perpendicular to *a b*, from the points *a*, *b*, and *c*; and let these perpendiculars be continued both upwards and downwards, as represented by *a o*, *c d* and *b f* in Fig. 14, and by the ticked lines in figures A and B.

Let the perpendicular at *b* be intersected in *f* by a level line drawn from the extreme of an arc of *nine* degrees, described through the breech of the gun from the centre *c* (Fig. 13) of the trunnion. Join *o f* (Fig. 14); then will the line *o f* represent the direction of an inclined plane capable of supporting the breech of the gun at every intermediate point from a horizontal position to nine degrees.

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* We may easily conceive a case in point. A vessel coming up with an adversary may heel more than 5°; but if on shortening sail for the purpose of close combat, the inclination be reduced to 3 or 4°, it would be necessary to shift the whole of the beds, unless it be previously determined that no firing shall take place until the vessels are regularly engaged.

† 2½ inches is an assumed dimension for the thinnest part of that portion of the coin which is intended to support the gun.

By construction, *o f* is bisected in *d*; if therefore *o d* and *d f* be successively introduced beneath the breech of the gun, it is manifest that the support will be perfect and *gradual* through every point within the range of 9°. This is the principle of the proposed coin.

In making *a b* equal to 36 inches, we assume a coin to be 2 feet long, which is about the common length, and that a distance of 3 inches at each extremity may be considered as over-length, thus leaving 18 inches for the *working*-length of a coin, and 36 inches for twice the working-length. Figs. A and B are each 24 inches long, and respectively show the exact form of a coin on the new principle, when lying flatways, and when placed upon its edge. The thicknesses at the extremes of the working-length of A are equal to *o a* and *c d;* and the thicknesses at the extremes of the working-length of B are respectively equal to *c d* and *b f;* consequently, after the coin ceases to raise the breech when used flatways (that is, with the depth *c d*), it will, when turned upon its edge, commence to give support at the same depth or angle, and continue to do so through the remaining degrees to the depth *b f*, supposing it to traverse upon a horizontal bed.

Again, it is evident that if the gun were supported horizontally upon the point *f*, the point *f* being brought to a level with the breech by *lowering the bed* sufficiently for that purpose, the breech would descend through 9° with the same regularity that it was before raised, provided the coin be *withdrawn* first on its edge and then flatways. Hence the same coin may be made to answer for the whole of the elevation, and the whole of the depression, if the bed upon which it is worked be properly adjusted for the distinct cases.

Figs. 16 and 18 represent the upper and lower sides of the bed, with the degrees marked thereon, to show the angles of elevation and depression. There is an index both on the side and edge of the coin, at one common point, so that while one is exposed the other is, of necessity, concealed; and *vice versa.*

These indices traverse across the graduations, and always point out the exact degree to which the gun is elevated.

A pair of side-chocks (or legs) as shown by a side-view Figs. 13 and 17, an end-view Fig. 15, and a horizontal view, Figs. 16 and 18, are securely attached to the bed by two bolts; and the bed is made just wide enough at this place to admit of the broadest part of the coin passing between them when traversing upon the bed in its reversed position.

It has previously been observed that the extreme elevation of naval guns is 9°, but that the depression is limited to 7°, therefore, at the point where the inclined line *o f* (Fig. 14) will depress the gun 2°, draw *x y* vertically. Apply *x y* in a vertical direction below the breech of the gun (Fig. 13); this will give a point in the upper part of a bed, which, being fixed horizontally, will allow a coin formed from the moulds A and B to support a gun horizontally upon the point *x*, and subsequently to depress it through every point extending to an angle of 7°. This is done to keep the bed as low as possible, which is desirable for several reasons, viz., it shortens the side-chocks (or legs), which are thereby rendered less liable to injury; it reduces the weight of the bed; it lessens the expense; and it furnishes a better bearing for the coin, as seen in Fig 13, than if only the over-length (or tip) of the coin were under the breech when the gun is at point-blank.

The legs are intended to stand upon a thin chock placed on the upper part of the axle tree. This chock will be a "regulation chock," varying in thickness according to the round of the beam at the several ports; and is introduced with a view to prevent any alterations in the beds after they are once made, thereby rendering any sets of beds always applicable to the same description of gun, and indiscriminately answerable to any port in a ship. The length of the side-chocks should be equal to the *sine* of 7°; or, equal to *f b*—*x y* (Fig. 14.)

When the bed is in its upper position, it is, as before stated, the distance *x y* (Fig. 14) = *sine* 2° + 2½ *inches*, below the breech of the gun; but when it is in its lower position, it is the distance *x y* + *sine of* 7° = 2½ *inches* + *sine* 9° = *f b* (Fig. 14) below the breech: and it is thrown into this last position by *reversing* the bed and placing its inner end upon an extra bed-bolt fitted to receive it. The bed is seen in a reversed position in Fig. 17, where *f* is the supposed point of horizontal support, from which the whole of the elevation is given, by withdrawing the coin successively on its edge and side.

The plan of giving the whole of the elevation with the bed in one position, and the whole of the depression with the bed in another position, is novel, and is less liable to mistake than when it is necessary to shift the bed while a ship is on the same tack, in consequence of a variation of inclination.

The method of obtaining the scales of graduation upon the beds may be very well understood, without letters of reference, by inspecting Figures 19 and 20, where the axis of the piece, the trunnion of the gun, the diameter of the breech, and the arcs described by the breech by introducing the coin successively on its side and edge, are shown. The degrees of the arcs are levelled over to the inclined lines representing the upper part of the coin in its two positions, and those points are then squared down to the base of the coin. In this manner we arrive at the horizontal distances through which the coin must traverse under all the varieties of elevation and depression; and this is all that need be done in actual practice in addition to what has been explained, with the exception of placing the *bed-bolts.*

To find the positions of the bed-bolts. Place the gun-carriage as nearly as possible in a situation similar to that in which it will stand when upon the deck; in other words, make an allowance for the round of the deck, in the distance between the fore and hinder trucks. An average of half an inch in a foot will be found to answer very well.

Draw a vertical line on the cheek of the carriage, passing through the centre of the trunnion of the gun, and upon this line set off a distance below the *axis* of the piece, equal to the *radius of breech* + $x\,y$ + *thickness of the bed*, and then draw a horizontal line through this point along the bracket of the carriage.

From the vertical line, set off, on the line last drawn, the length of that portion of the gun between the centre of the trunnion and the breech; this will give a point vertically below the breech when the gun is level. Set back 21 inches, that being the extreme distance that the coin will ever pass under the gun,—viz. 18 inches working-length, and 3 inches over-length, and make this point the position of the upper bolt *m*, Fig. 13. It will represent the under part of the bolt, admitting that the bolt has sunk its diameter into the score in the bed.

The lower bolt *p*, Fig. 13, will be as much below the upper one as the *length* of the side-chocks below the under part of the bed; consequently the bed, when reversed, will be parallel to its former position. Draw therefore another horizontal line upon the bracket of the carriage, and place the bed-bolt anywhere upon this line, so that it will afford a good bearing when the bed comes to rest upon it, and that the score upon the upper surface for the bed-bolt be situated between the graduations marked upon the top of the bed.

This explains the greatest difficulty that attaches to the plan, but it is one which was thought very little of by intelligent mechanics with whom I have had intercourse at the gun-wharfs on this service.

Every coin should be (like some recently fitted at Portsmouth) plated upon two of its surfaces from end to end, with a thin iron bar, about $1\frac{1}{4}$ inch broad, and $\frac{3}{16}$ of an inch thick (let in flush with the wood), to prevent the breech of the gun indenting the coin, which is an excellent preventive against one of the inaccuracies in practice often injurious to theory.

There is another casualty which ought to be guarded against, as affecting the height of the breech relatively to the trunnion, and which therefore alters the angle of elevation; it is the *shrinkage* of the trucks, especially the hinder ones, which, as they become seasoned, assume an elliptical form, owing to the contraction of wood being greater across the grain than in the direction of the fibre. This is by no means an unimportant consideration, though it may easily be rectified by making the trucks of two thicknesses (placing the grain of the wood crosswise), or by making them of timber less liable to alteration of form from atmospheric influence. We cannot attend too particularly to points like these, for the height of a ship's hull is not sufficient to justify the slightest disregard to contingencies which affect the vertical evolutions. Sir William Congreve has very justly said, "I do not hesitate to assert that without some well-organised instrument for pointing guns on board ship, with any motion in the vessel, there can be no certainty of practice even at 200 yards distance."

After the authorities that have been quoted, it cannot surely be questioned whether a gun ought to be supported with accuracy at every intermediate point between the limits of elevation and depression; nor can it be thought a too great refinement of principle, to insist on the advantages of an organised instrument for regulating the level of guns at sea, *methodically*, lest we should miss the hull of a ship even at 200 yards distance.

In conclusion. A model of a bed and coin constructed in the manner already described, and possessing the properties which it has been contended a bed and coin ought to possess, was first made in June last. It was shown to a few naval officers who expressed themselves much pleased with the plan; and in the course of the following month, it was submitted to the Hon. Captain Duncan, at the Ordnance.*

Nothing could be more gratifying than the liberality with which the proposition was received, and the facilities at all times afforded in every branch of the Ordnance Department.

Fourteen beds and coins were shortly afterwards fitted for trial on board his Majesty's ships Caledonia, Isis, Magicienne, and Pylades; and others would have been put on board the Asia and Revenge, if they could have been finished in time; but these ships, then lying at Spithead, were unexpectedly ordered to sea. Four sets of beds and coins were ordered for every ship excepting the Pylades, and she of course had them to her two bow guns only.

The opportunities now afforded for making experiments will soon determine whether the proposed beds and coins are superior to those at present used in the navy. If they should be found imperfect, the fault will be in the *detail;* for the principle is as demonstrable as any proposition in Euclid's elements.

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* Captain Blankley (commander of the Pylades) was one of the first who examined the model, and I am indebted to him for the honour of an introduction to Captain Duncan, and for having immediately applied for beds and coins on the principle recommended.

ART. VII.—*On the Protection of Ships from Lightning.* By W. SNOW HARRIS, Esq., F.R.S.—(Continued from page 446 of Vol. III.)

33. HAVING in some preceding observations pointed out the necessity of guarding the British navy against the operation of natural electricity, and entered upon the theory of lightning-rods generally, we have now to consider the most effectual methods of their application in ships; so as to obtain as complete protection in thunder-storms as can be reasonably expected from the advances yet made in natural knowledge.

34. It has been already observed (16), that in every case of damage from lightning, the electric matter is determined between the points of action through such line or lines, as, upon the whole, oppose to its progress the least comparative resistance; upon which simple and well-determined fact it is that we are enabled to derive protection in thunder-storms. It must be here remembered (11), that the materials of which ships and buildings are constructed, are themselves conductors of electricity, and are capable, alone, of transmitting, in a variety of instances, considerable quantities of natural electricity, (22). It may therefore be reasonably inferred, that, by completing a perfectly continuous and efficient line of metal from their most elevated points to the base on which they happen to be placed, the damage which so frequently occurs might be either greatly palliated or altogether avoided.

35. The application, therefore, of a lightning conductor, to a building or ship, must be always considered as a means of rendering more efficient the conducting power of the whole mass, so as to transmit such intense discharges of atmospheric electricity, as could not otherwise pass without intermediate explosion and damage. Thus, whilst the mast and rigging of a ship derive a direct protection from the metallic substance attached to it, the latter, in its turn, is relieved from as much of the action as the former is capable of transmitting. The following electrical experiments, which are new of their kind, will serve to illustrate this important fact.

(*a*) Let a fine wire of iron, about the $\frac{1}{200}$th of an inch in diameter, and about twelve inches in length, be stretched perpendicularly between two insulated points, and let such a charge of artificial electricity be accumulated, and transmitted through this wire, as will *just* fuse it, but not more. Let a similar length of wire from the same reel be now closely applied to a cylindrical piece of rather damp wood, and placed between the same points as before. If a similar accumulation be now discharged upon the wire, the wire will remain perfect; the transmitting power of the damp wood being sufficient to protect it from that particular accumulation.*

(β) Let a similar wire to the preceding be caused to pass through the centre of a finely-exhausted receiver, it will now be extremely difficult to fuse it by any ordinary charge which we can accumulate; the little resistance offered by the vacuum to the superabundant quantity of electric matter being sufficient to prevent it from passing through the metal. It is, in fact, on the principle above stated (16), less difficult for the electric matter to pass through the vacuum than through the wire, at the point of fusion. I have known an extremely fine iron wire treated in this way, which remained perfect under an explosion from twenty square feet of coated glass, highly charged, whilst in air it became fused by the charge of a small jar.

(γ) Let a model of a mast of about six feet in height be constructed, in two vertical parts, having an interrupted line of metallic wire passed through its centre longitudinally, so as to insert, between the opposed points of the wire which may be about one-fourth of an inch apart, or more, a quantity of percussion-powder, and let such a charge be accumulated as will pass freely over these interruptions; the powder between the points will, on passing the charge through the mast, become exploded, and the parts of the mast thrown asunder. Let the whole be again replaced as before, and an extremely fine wire, or slip of gold leaf, attached to the mast. In this case an accumulation may be discharged upon the whole, nearly equal to the fusion of the wire, before any portion of the charge will pass inside in the interrupted circuit, and force the parts asunder, so that, with the same accumulation as before, the mast will remain perfect. If the intervals between the wire inside the mast be sufficiently great, then the protecting wire may even undergo complete fusion, without the powder inside becoming exploded.

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* This is a somewhat delicate experiment, and requires a very careful adjustment of the accumulation by which the wire is to be fused. For an accurate method of effecting this, see Transactions of the Plymouth Institution, vol. i. p. 94. See 44.

36. Since damage in thunder-storms only occurs when the electric matter cannot be transmitted with sufficient rapidity, as in the cases above cited (n) (o) (22), it may be hence fairly inferred, that although we should never come to know the actual quantity of electric matter liable to be discharged in a thunder-storm, we have, nevertheless, by increasing the conducting power of the mass, multiplied the chances of escape in an extraordinary degree. Mr. Cavendish has proved, that even the conducting power of water is a million times less than that of iron wire.* It appears from a notice given by Mr. Cavendish, of some experiments he has made on this subject, that iron wire conducts about four hundred million times better than distilled water.

37. Although the application of lightning-conductors to buildings on shore is always judicious, and the resulting advantages fully apparent, yet on ship-board, where the effects of lightning are still more to be dreaded, the introduction of this means of defence has been slow and imperfect. On shore, stationary elevations may be defended by means of rigid metallic rods, which may be either perpendicular, or carried over projecting portions of the edifice, withour impairing their efficacy. On ship-board, however, the case is widely different. The masts, though erect, consist of many distinct portions; these it is often necessary to move one upon another, and sometimes to remove altogether; they are also liable to damage from wind and other accidents; whilst the quantity of cordage and canvas, so constantly about the masts, often necessarily renders the condition of a lightning-conductor still more complicated. With a view of meeting these difficulties, the conductors employed at sea usually consist of long links of metal, or chains, about the size of a goose-quill, forming a semi-flexible metallic line; they are sometimes made of iron. Those

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* Transactions of the Royal Society.

employed in his Majesty's navy, however, are of copper; they are attached to a hemp cord, and, being packed in a box, are intended to be set up from the mast head when occasion requires; so that, as observed by Mr. Singer, in his excellent work on electricity, partly from inattention and partly from prejudice, they frequently remain unemployed in the ship's hold during long and hazardous voyages; a remark the truth of which is but too frequently verified, in the damage which so frequently occurs at sea in severe storms of lightning.* (n) (o).

38. These conducting chains above mentioned, beside being uncertain in their application, are, in a variety of instances, but ill-adapted to the circumstances under which they are to be placed; inasmuch as they are open to every sort of external violence incident to a ship's rigging, and are very liable to be deranged in their situation, more especially in gales of wind, at night, when the ship is under sail; and when, perhaps, it is required to remove the higher portions of the masts altogether. They must, therefore, be considered only as inconvenient substitutes for fixed and more extensive masses of metal, of uninterrupted continuity, the great want of which, in every kind of chain, is extremely unfavourable to the free transmission of large quantities of electricity, whilst the electric matter, in becoming sensible at the points of junction, frequently disunites the chain at each link by its expansive force. (o).

39. The above considerations, together with the damage which so frequently occurs to ships in thunder-storms, are alone sufficient inducements for attempting the application of such permanent conductors on ship-board as may at all times be competent to afford security, which may be always in place, and always ready to meet the most unexpected danger, without being in the least degree dependent on the exertions of the crew.

40. In order to effect this, it becomes essential to complete the conducting power of the masts themselves, up to the greatest possible extent consistent with convenience in practice, seeing

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* A minute account of the case of damage by lightning, on board the New York Packet, may be seen in the Liverpool Chronicle, May 1827, from which it appears that the conducting chain, at the time of the first explosion (n), was carefully stowed away in its box in the ship's hold, although set up in time to avert the effects of the subsequent explosion (o).

(11) that the masts are already so circumstanced that the course of a stroke of lightning is actually determined by their necessary position, immediately through the body of the vessel, and which is the more exposed on that account to damage, if the conducting power of the masts remains low and unassisted. It will be therefore requisite to identify with the masts, a continuous line of metal from the vane-spindle at the mast-head to the sea.

41. For this purpose a sort of double conductor, of a superficial kind, consisting of two separate laminæ of metal, placed one on the other, may be easily formed of sheet copper, in short lengths of about four feet; the two laminæ may be so united as to cause the butts or points of the one layer to fall immediately under the continuous portions of the other. The width of this conductor may vary from an inch and a half to six inches, according to the size of the mast, the whole thickness being about 3-16ths of an inch. The lengths must be first secured by means of rivets, at the points of junction, so as to form a perfectly continuous and elastic line of metal; this is to be inserted under the edge of a neat dove-tailed groove, ploughed longitudinally, in the aft sides of the masts, where it is subsequently secured by means of wrought copper nails, so as to have a fair surface; the nails are driven at each side, about four inches apart. The groove, previously to applying the metal, should be freely painted over with white lead, and must be sufficiently deep to allow of the copper being somewhat below the surface of the wood.

42. The metallic line thus formed will then pass from the vane-spindle, or extremity of the mast, along the aft sides of the royal mast and top-gallant mast, being connected in its course with the copper about the sheave-holes. A copper lining in the aft side of the hole in the cap through which the top-gallant mast slides, may now carry on the connexion, and continue it over the cap to the aft side of the topmast, and so on to the step of the mast; here a wide copper band is to be turned round the step under the heel of the mast, resting on a similar band of copper, which traverses the keelson longitudinally, connecting together for eight or ten feet on each side of the step all the keelson bolts; these bolts should have

a perfect and good contact with the copper inserted between the keel and false keel externally. In lieu of these bolts the copper band on the keelson may be connected with three or four perpendicular bolts of copper, varying from one to two inches in diameter, which may be driven, expressly for the purpose, into the main keel, upon as many transverse or horizontal bolts brought into immediate contact with the copper expanded on the bottom.* The laminæ of copper are to be turned over the respective mast-heads, and completely round the heel of the mast, being secured on the opposite sides for about an inch or more in length. The copper connexions in the caps are to be prepared in a similar way, each of them being continued from the lining in the aft side of the round hole, over the cap into the fore part of the square one, where the metallic band is turned over and secured as before, so that when the cap is in its place the contact is complete.

43. Beside the connexions with the keelson bolts, wide conducting bands, formed as before, should be led out on each side transversely, from under the beams nearest the masts, immediately to the iron knees or other metallic fastenings in the sides. In this way all the detached masses of metal of consequence in the hull will be completely connected with the conductors on the masts, through the intervention of the copper expanded on the bottom—a condition of the utmost consequence, as the action of the conductors is, in fact, nothing more than a rapid diffusion and equalization of the electric action, by which the concentrated and dense explosion is avoided.

44. The conductors under the beams are connected with those on the mast, by means of a sliding bolt, or otherwise by the intervention of copper plates inserted in a simple and ingenious manner between the mast and beams, so as to ensure a perfect contact as suggested by Mr. Rice, of his Majesty's dock-yard at Chatham.

45. A lightning-conductor thus applied to the mast of a ship, adds considerable strength to the mast itself, of which it is made

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* When the mizen-mast does not step on the keelson, metallic connexions must be continued to the keelson bolts and other metallic fastenings, immediately from the termination of the conductor in the step, in any way most convenient.

to form a portion,* and is capable of resisting any external force; whilst, by presenting a fair surface, it admits of the parrel of a yard traversing the mast with ease; and being secured in short lengths, so as to form a series of close joints, will readily accommodate itself to any curve which the mast can stand under. A very perfect continuity is also maintained under all the varying positions of the masts, and there is a sufficient quantity of metal to ensure a very rapid transmission of the electric matter; it has, besides this, the capital advantage of being applied immediately to the object to be defended. (Exp. *a.*)

In the operation of such a conductor, it is further evident, that whatever position we suppose the sliding masts to assume, whether partially struck or otherwise, still there is a perfectly continuous line of conduction to the sea, since that portion of the conductor which remains below the caps and tops when the higher masts are struck, or partially so, is no longer in the line of action, it has consequently no longer any influence in the operation of transmitting the electric matter.

46. The conducting power of metallic bodies appears to vary considerably, although for very low electrical actions they may be considered as equal; the differences, however, become greater in proportion to the extent of the charge to be transmitted. Copper has, in all intense actions, a decided superiority over every other metal except silver; it is therefore on this account alone, well adapted for the purpose of a lightning-conductor; besides which, it is very manageable: compared with iron, a metal frequently employed in the construction of conductors, it was found in some particular instances to resist the heating effect of a given charge in the ratio of

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* The result of an extensive series of experiments, carried on in his Majesty's dock-yard at Portsmouth, showed that a flexible spar with the attached conductor, required a mean force of 48lbs. upon 5 cwt., in order to bring it to the same point of flexure as when the conductor was not present—the spar being submitted to experiment on its eight squares; whilst in some positions it required upwards of 100lbs. to deflect it to the same point, that is, nearly 1-5th of the above weight. Now, although we cannot say, that the more flexible the spar the sooner it will break, yet it may be reasonably inferred, that in the *same* spar, anything which tends to give it greater stability, and prevent it from reaching under a given force, that point of flexure at which it may be supposed to fracture must necessarily add to it strength.

5 to 1.[*] Dr. Priestly has also observed, that the force required to fuse a wire of copper of a given diameter, would most probably dissipate an iron wire of *twice* that same diameter.[†] Mr. Singer also observes, that when a conductor is wholly of copper, it may be thinner than if made of iron.[‡]

47. The following Table shows the extent of a conductor on the proposed plan (41), on one mast of a frigate of 50 guns as compared with the copper links usually employed in the British navy, together with the necessary equivalent in copper or iron bolt, in order to obtain a conductor of the same value. It has been calculated on the supposition that the two laminæ of copper forming the conductor are 1-8th and 1-16th of an inch in thickness respectively throughout.

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[*] Hist. of Electricity, p. 638.

[†] Singer's Electricity, p. 226.

[‡] See "Transactions of the Royal Society" for the year 1827, p. 22.

TABLE

	1		2		3			4		5	
SUCCESSION OF MASTS.	Proposed Conductors.		Equivalent in a Copper Rod.		Equivalents in an Iron Rod, taking Conducting Powers only as four to one.			Mass and Surface in a Copper Rod of half-inch diameter.		Mass and Surface in present Conductors.	
	Mass.	Surface.	Diameter.	Surface.	Mass.	Surface.	Diameter.	Mass.	Surface.	Mass.	Surface.
ROYAL POLE CONDUCTOR.	Cubic inches.	Square inches.	Inches.	Square inches.	Cubic inches.	Square inches.	Inches.	Cubic inches.	Square inches.	Cubic inches.	Square inches.
Copper plates; 18 feet 3 inches long, 2 inches mean width	82	1752	·69	474	328	949	1·38	42	343	10·5	171
TOPGALLANT-MAST CONDUCTOR.											
17 feet long .... 2½ inches wide	95	2040	·77	493	380	986	1·54	40	320	10	160
TOPMAST CONDUCTOR.											
50 feet long and .... 4 inches wide........................	450	9600	·97	1463	1800	2926	1·95	117	942	19·2	471
LOWER-MAST CONDUCTOR.											
93 feet long and .... 6 inches wide	1255	26784	1·20	4212	5020	8424	2·20	219	1753	54·7	876
Total...........................	1882	40176	1·058	7119	7528	14238	2·116	418	3358	94·4	1678

The resulting quantities in the *last* line at the bottom of the table represent, with the exception of the new conductors, the masses, surfaces, and diameters, of cylindrical metallic rods, supposed to extend the whole length of the mast. Thus, in column 2, we have the diameter and surface of a copper rod containing 1882 cubic inches of metal, being an equal quantity of matter to that in the new conductors, and the sums therefore are not the result of the addition of the successive masts. The same may be observed in column 3, taking the equivalent in iron. In the fourth column we have the mass and surface of a copper rod of half an inch in diameter, generally considered as adequate to transmit any stroke of lightning as yet experienced; and, lastly, in column 5 we have the mass and surface in the conductors now furnished to the British navy.

48. The objections which have been urged to the conductors above-mentioned are, for the most part, such as have been already combated in the preceding pages (19), and therefore require but little further consideration. It has been said, however, in addition, that since we can never come to know the extent of every possible discharge of atmospheric electricity, the superficial conductors may become fused;—that in fixing conductors in the masts we can only have surface, whereas a dense mass of metal is requisite, if we wish to prevent fusion; hence the metallic surfaces are calculated to bring destruction on the vessel;—that the conductors are objectionable, in consequence of their passing immediately through the body of the vessel, and consequently near the magazines; and lastly, that in a mechanical point of view, the plates of copper are not likely to stand the pressure of sail and working of the masts. We shall, as before, proceed briefly to consider those additional objections, which, it must be admitted, are in themselves very reasonable matters of discussion, and very fairly urged.

49. The notion that a ship can possibly be in a worse condition *with* than *without* the conductor, has been already shown (24) to be an erroneous one. Indeed, the reverse of it appears to be nearer the truth (36), since, as has been just stated, although we *should never know* the actual quantity of electric matter which may possibly be discharged in a thunder-storm,

we have, nevertheless, by completing the conducting power of the masts, greatly multiplied the chances of escape.

50. With respect to the absolute fusion of the conductors, it may be laid down as an axiom, that a given quantity of metal can always transmit any electrical accumulation equivalent to its fusion: this is evident, since the fusion arises from the electric matter actually transmitted. Now, on a review of the various cases of damage by lightning, it cannot be said that a conductor equal to a copper rod of 1,058 inches diameter, and 210 feet in length, which may be taken as the mean value of the conductor on one mast of a frigate of 50 guns, is at all likely to be fused. In short, the evidence we possess from actual experience (28) is conclusive against such an opinion, and goes far to prove, that little short of an atmospheric explosion from electrical action, capable of involving the ship and everything on board in one common ruin, could dissipate so great an extent of metal. Such un-heard of and unknown convulsions we pretend not, as already observed (28), to have any power of withstanding.

In the foregoing considerations we have only taken into account the action of a single mast; but it is fair to presume, that the conductors on each mast would be brought into action before any single one could undergo fusion, in illustration of which I shall cite the following experiments.

(δ) Let a single and very fine wire of iron be stretched in a perpendicular direction between two horizontal insulators, and immediately under a larger conducting ball, from which an explosion may be caused to pass, just sufficient to fuse the wire. If a second wire, stretched in a similar way, be now added, and placed near the first, so as to be equi-distant from the large conducting ball, the explosion will break upon the two, but neither will be fused. Let now an accumulation be obtained capable of fusing both the wires. Then, if three wires be placed under the conductors, the explosion will divide upon the three, and neither will be fused. The discharge is here supposed to pass upon spheres, between which the wires are secured; but if a pointed termination be given to the spheres, then the single wire will be no longer fused with the same extent of charge. We may hence infer, that previously to either of the conductors being fused, the others would be brought into action (16), and that hence we may fairly calculate on the fusion of all or none.

51. If therefore, we add to the great capacity of the conductors in question their conjoint action, and the very favourable conditions under which they are placed, that is to say, their pointed terminations above, and their perfectly uninsulated state below, we have every reason to repose confidence in their efficiency. So that, instead of the disastrous results arising to ships from atmospheric electricity, we should find the electric matter rapidly dissipated, and transmitted, in a state of such low tension, to the sea, that, in a great variety of cases, no explosion would be found to occur. Indeed, such seems to have been actually the case in his Majesty's frigate Dryad, now on the coast of Africa, under the command of Commodore Hayes, and one of the few ships in the British navy equipped with lightning-conductors on the plan above detailed. I learn, from my friend Captain Turner, of the above ship, whose intelligence, in everything connected with his profession, is only exceeded by his anxiety to promote its interests, that after having experienced some severe lightning on the coast, they encountered a tornado, during which both the fore-mast and mizen-mast were assailed at different times by heavy discharges of lightning. The electric matter fell on the conductors so freely, that in passing them, it produced a sort of luminous atmosphere, and escaped through the hull with a noise resembling the violent boiling of water; a result, he says, which has given all on board the greatest confidence in the efficiency of lightning-protectors, when properly applied.*

52. It is a mistake to suppose that the conductors thus superficially applied to the masts, are without considerable powers, when considered even in relation to their thickness, as may be seen by reference to the Table above given (45); moreover, admitting that quantity of metal *is* the great desideratum in a conductor, still it must be equally efficient in any form: for the conducting power of the mass must consist

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* I have every reason to believe that an express communication on this subject was sent to the Lords Commissioners of the Admiralty, by Commodore Hayes

of the conducting power of all the parts of that mass. Now it would be absurd to suppose that a mass of metal, expanded into any extent of surface, does not still conduct in all its parts; indeed, our experience of the effect of electricity on metals is quite conclusive in this question, since it is impossible to destroy a portion of a perfectly homogeneous metallic surface, of uniform density and thickness, by an artificial accumulation of electricity, without destroying the whole. We do not take into the account here any immediate edge or single point upon which the discharge is first concentrated.

53. It would seem, from the fine and conclusive experiments of Sir H. Davy,* that a considerable advantage is obtained by expanding a mass of metal into an extensive surface; since, by so doing, we expose it to a greater extent of cool air, by which its temperature is kept low, and the heat caused by the discharge much diminished. That the conducting power of metal is greatly impaired by increase of temperature is a fact beyond a question; the very few experiments adduced to the contrary are altogether inconclusive. A given quantity of metal, therefore, formed into a hollow tube, might possibly withstand an intense discharge; whilst in the form of a solid rod it would become fused.

54. The circumstance of the conductors passing through the ship is not any objection of any moment, more especially, as already so often insisted on, when we take into account the situation of the masts themselves, which, in almost every instance, determine the course of the electric matter in that direction. Moreover, we invariably find, as is well observed in the "Transactions of the Royal Society," that in most cases of lightning on ship-board no mischief occurs after the lightning reaches the well. That the electric matter may be safely carried through the ship to the sea is very evident from experience; it is, in fact, owing to the metallic fastenings, which admit of this operation going on, that most of the ships struck by lightning are saved from extensive damage in the hull. We find such to be more peculiarly the case in his Majesty's ships, where metallic fastenings are in abundance; and which, being

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* Transactions of the Royal Society.

all actually, or very nearly connected with each other, by means of the copper expanded on the bottom, cause the electric action to be rapidly equalized in the vessel and surrounding water: it is, indeed, not a little remarkable, that the more serious cases of damage in the hull have occurred in merchant vessels, where metallic fastenings have been little prevalent. In fnrther illustration of this important fact, we may cite the case of his Majesty's ship London, in which the fore-mast was shivered to the keel, whilst the keelson, step, and keel remained perfect.

55. That the conductors pass *near* the magazines is allowed; but such is the case, to a great degree, in all magazines defended by lightning-conductors; they are necessarily placed near them for their protection; for we well know that the electric matter will not leave a *good conductor in the line of action* to pass upon detached or less perfect conductors out of that line (Exp. 7, s. 35). We may therefore certainly infer, that whenever the lightning is fairly led to the conductor in the hull, the danger is over. Without the conductors, damage in the way above-mentioned is by no means unlikely. Thus, in some vessels, there is not unfrequently an iron spindle, upon which the capstan is supported, immediately over the after-magazine. This would inevitably transmit the electric matter to the point in which the spindle terminates, from which it would fly off in a dense and concentrated form, to the next point which happened to lie in the line of action. The same reasoning applies to the masts, which, if not exclusively made the line of action, would admit of the electric matter being transmitted through such other points as might, upon the whole, be found to oppose to its progress the least resistance.

56. The mechanical application to the masts is an objection of a more palpable kind, and can be only met by experience; with the exception of a few trifling instances, in one or two ships already fitted, little defect has occurred. In the Dryad, above-mentioned (49), no complaint whatever is made—rather on the contrary. The copper is stated to stand extremely well on the masts, notwithstanding that the masts have been frequently exposed to a heavy press of sail in chase, and likewise to very severe weather. Now it must be remembered, that this ship has passed from a cold to a burning climate. It would, how-

ever, be surprising, if the infancy of any contrivance were to be equally perfect with its more advanced state, or that every difficulty possible to occur in practice could be at once foreseen and provided against. From the circumstance of the conductor being constructed in many parts, there appears every reasonable ground for believing, that when perfectly applied on the masts, the copper will withstand any action which it may be fairly liable to, consistent with the safety of the mast itself. In the experiments above alluded to (45), a spar, with the attached conductor, was repeatedly submitted to an extreme flexure by weights, without at all deranging the copper, which seemed to play freely with the bending of the spar; on the weights being withdrawn, the whole returned to the previous line of direction, to within the 1-50th part of an inch, as measured by an index placed on the axis of a small wheel delicately hung, and which carried a fine silk line and counterpoise attached to the centre of the spar; the elasticity of the whole therefore seemed very perfect.

57. If I have been at all successful in the preceding observations on the protection of ships from lightning, we may venture to affirm, that the proposed method of defence is efficient and practicable, and if carried generally into effect, is likely to be productive of very beneficial consequences to shipping generally; besides that, it must be satisfactory to know, that we have availed ourselves of the means which science has so long suggested, and which experience has confirmed, of avoiding the fatal consequences resulting to ships from strokes of lightning. In the present state of the question, these means may be considered as either ineffectually applied, in the greater number of instances, or otherwise totally neglected. It must be considered as matter of regret, that a discovery considered by scientific persons as one of the most important yet arrived at by electrical inquiries, and offering the greatest practical advantages, should, for so long a time, have been unproductive of all the benefits of which it is susceptible; for although buildings on shore have, for a long period, been effectually protected, by means of lightning-rods, against the danger arising from atmospheric electricity, yet it must be admitted that, during

the same lapse of time, ships have been constantly suffering from this source of danger.

58. Although this subject has not been properly appreciated by many persons, under an impression that the chances of damage from lightning are too few and inconsiderable to warrant even the little trouble and expense necessary to avoid them; yet I trust to have made it appear that such opinions are by no means founded on reflection, and that a judicious application of fixed and continuous lightning protectors, on shipboard, is not only desirable for shipping generally, but is in a great variety of instances absolutely essential to their preservation.

Plymouth, Dec. 14, 1831.

ART. VIII.—*A List of Patents which have been taken out since the* 1*st of July,* 1831, *for Inventions or Improvements connected with Naval Affairs; with Extracts from Specifications, &c.*

To Thomas Westrup and William Gibbins, both of Bromley, in the county of Middlesex, gents., for improvements in converting salt or other water into pure or other water. Dated May 24th, 1831.

To Jacob Perkins, of Fleet-street, in the city of London, engineer, for improvements in generating steam. Dated July 2d, 1831.

To Baron Charles Wetterstedt, of Whitechapel-road, in the county of Middlesex, for a composition or combination of materials for sheathing, painting, or preserving ships' bottoms, and for other purposes. Dated July 6th, 1831.

To Moses Poole, of Lincoln's-inn, in the county of Middlesex, gent., for certain improvements in steam-engines, and in propelling boats and other floating bodies, parts of which improvements are applicable to other purposes. Communicated by a foreigner. Dated July 13th, 1831.

To Augustus Demondiou, of Old Fish-street-hill, in the city of London, for certain improvements on guns, muskets, and other fire-arms, and in cartridges to be used therewith, and method of priming the same; and in the machinery for making the said guns, muskets, and fire-arms; also the cartridges and priming; which improvements are also applicable to other purposes. Communicated by a foreigner. Dated July 13th, 1831.

To William Batten, of Rochester, in the county of Kent, gent., for an apparatus for checking or stopping chain-cables; which apparatus may be applied to other purposes. Dated 13th July, 1831.

To John de Burgh, Marquis of Clanricarde, for certain improvements in fire-arms, and in the projectiles to be used therewith. Communicated by a foreigner. Dated July 15th, 1831.

To Sir James Caleb Anderson, of Buttevant-castle, in the county of Cork, Ireland, baronet, for certain improved machinery for propelling vessels on water, which machinery is applicable to other useful purposes. Dated August 2d, 1831.

To George Holworthy Palmer, of Manchester-street, Grays-inn-road, civil engineer, for certain improvements in the steam-engine, boiler, and apparatus, or machinery connected therewith, applicable to propelling vessels, carriages, and other purposes. Dated September 16th, 1831.

To Mark Cosnahan, of the Isle of Man, esquire, for certain improvements in apparatus, modes, or process, for converting sea or salt water, and also other brackish, turbid, or impure waters, into purified or fresh water; which apparatus, modes, or processes, or parts thereof, may be applied to other purposes. Dated September 20th, 1831.

To William Bingham, of St. Mary Hall, esquire, and William Dupe, gun-maker, both of Oxford, for certain improvements on fire-arms of different descriptions. Dated September 24th, 1831.

To Henry Hope Werninck, of North-terrace, Camberwell, in the county of Surrey, gent., for certain improvements in apparatus or methods for preserving lives of persons and property when in danger by shipwreck, by speedily converting boats or small vessels of ordinary description into life-boats, and other apparatus or means applicable to the same objects. Communicated by a foreigner. Dated September 24th, 1831.

To Oliver St. George, of Great Cumberland-street, in the county of Middlesex, esquire, for certain improvements in machinery for acquiring power in tides or currents. Communicated by a foreigner. Dated September 28th, 1831.

To Miles Berry, of the Office for Patents, 66, Chancery-lane, in the parish of St. Andrew, Holborn, in the county of Middlesix, engineer and mechanical draftsman, communicated by M. Jean Nicholas Senéchal, *Ingenieur des Ponts et Chassees*, residing at Versailles, in France, for certain improvements in the boilers or generators of steam or other vapour, and in engines to be worked by steam or vapour, for propelling or actuating machinery on land, and vessels or other floating bodies on water; and also in the mode of condensing such steam or vapour. Dated September 28th, 1831.

To William Hale, of Colchester, in the county of Essex, machinist, for improvements in machinery, or apparatus for propelling vessels, which improvements are also applicable for raising or forcing fluids. Dated October 13th, 1831.

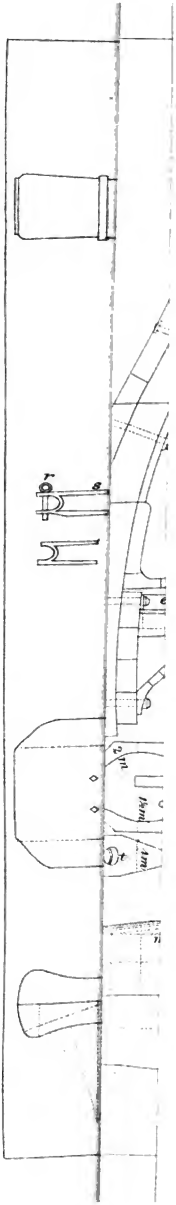
To Arthur Howe Holdsworth, of Dartmouth, in the county of Devon, esq., for improvements in the contstruction of rudders, and in the application of the same to certain descriptions of ships and vessels. Dated November 19th, 1831.

Extracts from Specifications, and Remarks.

Extracts from the Specification of Mr. Jeffrey Shore's Improvement on Tackle and other Hooks, which he denominates the "Self-relieving Hooks."—My invention consists in the application of a weight to one end of a hook, whereby, so soon as the boat or other load is supported by other means, the weighted end causes the hook to be relieved or unhooked; but in order that my invention may be more readily understood and carried into effect, I will proceed to describe the drawing hereunto annexed.

Figure 21 represents a block with two sheaves, and fig. 22, a block with one sheave, and Fig. 23 shows a side view to each, of which a hook, constructed according to my invention, is applied. Fig. 24 represents a hook to be used without a block. In each of these figures the same letters indicate similar parts: *a* being the hook, *b* the strap which descends below the block, *c* a pin passing through the strap *b* and the hook *a*, and thus acting as a fulcrum or axis on which the hook turns; *d* is a continuation of the hook beyond the pin *c*, and this part *d* is made more heavy, so that when the load which has been suspended by the hook becomes supported by some other means, the part *d* will descend, as shown by dotted lines, and cause the hook to be withdrawn or unhooked. I will now suppose a boat suspended by two of these hooks to the stern or quarter of a vessel, when, if it be desired that the boat should be lowered, all that will be necessary, will be to slacken away till the boat is on the water, and supported by it, when the hooks being no longer pressed upon by the weight of the boat, the parts *d* of the hooks will descend and withdraw the hooks, whereby the boat will be relieved from the hooks, and may be hauled alongside, and thus the difficulty and danger which are experienced in lowering the boat when the sea runs high are avoided, and the boat may be hoisted with much greater facility, for it will only be necessary to reeve the lines *e* attached to the point of the hooks through the ring-bolts and haul on, which will bring the hooks through the ring-bolts, when the boat will hang on the hooks, and may be hoisted; and these hooks may be made still more secure from unhooking, by taking a single turn with each of the lines *e* (see Fig. 21) affixed to the point of the hook, and making a hitch round the projecting pin *d;* the hooks will be moused and perfectly secure from unhooking. These hooks may also be used as common hooks, by passing a line through in the hole of the part *d* of the hook, and by making the end *d* of the hook fast to the strap *b.*

Observations communicated by the Patentee.—The following observations may explain the use of this invention more fully. Suppose you are lowering a boat from the ship's quarter, and you are fearful of the head tackle coming unhooked, first you will let the stern tackle unhook itself, and a man in the head of the boat will hold the line attached to the point of the hook in his hand, with one turn over the pin, until such time as the boat is in the water, then, by throwing off the hitch, the boat will be clear. In hoisting up boats, when you bring the boat alongside to hoist her up, you will reeve the line through the ring-bolt, and pull upon it, which will haul the hook into its place; then one turn round the pin mouses the hook, and makes it perfectly secure: you will thereby save the men's fingers from being jammed, and the boat from being dashed against the side of the ship, perhaps two or three times. To consider this hook in the most awkward situation, which is when used for the stern-boat, and you have a man overboard, the ship is going fast through the water—she goes so fast that the boat, when touching the water, before the weight is all off, goes astern of the ship faster than the hook falls; it will not then unhook itself in that case; the men in the boat should whip their hands round the fall, and their knees against the boat-side, and give her a shake towards the ship's stern; two inches will be enough, it will be sure to unhook. It will be evident from this explanation, that this hook cannot fail; and I may add, that in all cases in which they have been used at sea they have met with most decided approbation; to which purport I have certificates from officers both of the Royal and Mercantile navies.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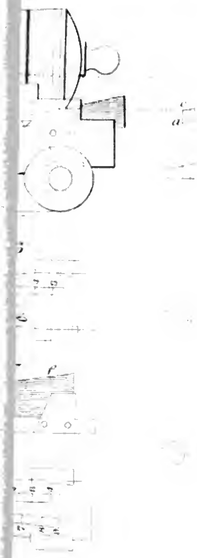

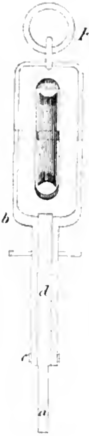
Fig. 2

Price 2s. 6d. *November 1st,* 1865.

PAPERS

ON

NAVAL ARCHITECTURE,

AND OTHER SUBJECTS CONNECTED WITH

NAVAL SCIENCE.

> "The philosopher may very justly be delighted with the extent of his views, and the artificer with the readiness of his hands: but let the one remember that without mechanical performance refined speculation is an empty dream, and the other that without theoretical reasoning dexterity is little more than a brutal instinct."—*Rambler*, No. 9.

NO. XIV.—VOL. IV.

LONDON:
WHITTAKER AND CO., AVE MARIA LANE.
1865.

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ADVERTISEMENT.

The Editors having observed the want of a scientific publication on this important National and Commercial subject, have been induced to revive the "*Papers on Naval Architecture.*" They feel they cannot do better, as illustrating their views, than to reproduce the Advertisement of Messrs. Morgan and Creuze, which accompanied the First Volume of these Papers in 1826:—

"The state of the science of Naval Architecture is very imperfectly known in this country, arising not more from the difficulty of the subject than from the smallness of the number, and the character of the works, published on it. The abstruse manner in which it is necessary to treat many parts of the theory, and the wholly practical manner in which the construction of a ship is generally treated, render these works far better adapted for the student than for the general reader.

"It is proposed, in this work, by a combination of popular and scientific papers, to give a general view of the theory and practice of Naval Architecture. The increasing interest this subject has lately excited appears to render such a work desirable.

"All pretensions to the discovery of secrets in Naval Architecture will be disclaimed, as altogether inconsistent with the nature of the subject. The means of improvement in this science are the collection of facts, experiment, mathematical reasoning, and general observation; and success is to be expected only in proportion to the talent and labour devoted to it. The extent and difficulty of the subject render a very rapid advancement improbable; but there is nothing in its character which can be shown to prevent the general mode of philosophical investigation being equally applicable to this as to other sciences; and it is reasonably to be expected, that, by equal attention to it, it will advance certainly, though slowly, to the same degree of excellency. While the conductors of this work believe mathematics to be so closely connected with its improvement, that many of its branches cannot be understood without it, they yet consider that the judicious opinion of experienced men, however unconnected with scientific reasoning, is to be received with the greatest respect, as tending to enlarge our knowledge, and direct future investigation in this science.

> "It will be the object of this work to collect all the information that can be obtained on Naval Architecture, and other subjects connected with Naval Science. It will relate particularly to the Design of our Ships, their Construction, the Nature of the Materials of which they are built, and the Direction of them at sea. The matter of this work will be composed of Original Papers, Translations, and Extracts from works on Naval Science, Critical Remarks, and Correspondence.
>
> "It is considered that, by having a work wholly devoted to this subject, much useful matter will be obtained, which would otherwise remain unpublished; particularly, it is hoped, the observations of naval officers, by a combination of whose valuable experience with the theoretical knowledge of the naval architect, much advantage to this science may be expected."

It is believed this publication will be found a valuable coadjutor to the Institution of Naval Architects in advancing the science of Naval Architecture and Navigation, and the art of Shipbuilding.

London, November 1st, 1865.

All communications to be addressed to the Editors,
4, *East India Avenue, London, E.C.*

CONTENTS

OF

No. XIV.

Page

Art. IX. Remarks on Sea-going Qualities - - - 113

X. Naval Architecture. Its Rise, Progress, and Present State. A Lecture delivered by Charles F. Henwood, Esq., N.A., at Blackheath, on the 23rd of October, 1865 - 116

XI. Remarks on the Mackay Gun - - - 141

XII. The Turret or Central System of Captain Cowper P. Coles, R.N.; its present Phase - 152

XIII. An Inquiry respecting the Form of least Resistance for a Ship; the Position of the Centre of Gravity with respect to the Ship's length; and the means of Reducing the Motions of Pitching and 'Scending to a minimum. By William Henwood, Esq., N.A., Member of the late School of Naval Architecture.—(Being a Reprint from the "United Service Journal" for 1833) - - - - - 157

Page
XIV. Patent for raising Screw-Propellers in the Royal and Merchant Navy, when Ships are not built with a Screw-well. By CAPTAIN HALL, C.B., R.N., Superintendent of Her Majesty's Dockyard, Sheerness - - 185
XV. Rigg's Patent Duplex Propeller. By MR. RUMBLE, Inspector of Machinery Afloat, R.N. 188
XVI. Essay on the Resistance of Fluids. (Being a Reprint from the "Encyclopediæ Edinensis") 196
XVII. Miscellaneous - - - - - - 209
XVIII. Launches in October - - - - - 210
XIX. Trial Trips in October - - - - - 212
XX. List of Patents on Naval Subjects - - 219

PAPERS

ON

NAVAL ARCHITECTURE,

&c.

Art. IX.—*Remarks on Sea-going Qualities.*

Naval Architecture presents a vast field for inquiry and investigation. But it is a lamentable fact that there exists no theory of construction which commends itself to science or experience. It will be our endeavour, by the collection of facts, to supply materials on which to found a system. Correctness of observation is an essential element of success, and we must trust almost entirely to the sailor for the performances of ships at sea. The angles of rolling should be accurately recorded, with the attendant circumstances and periods of oscillation; also the angles of pitching and 'scending; but, to assist the sailor in the observations, he should be supplied with a diagram of his ship, with scale of displacement, position of centre of gravity, centre of effort of sails, and centre of gravity of cargo spaces. In fact, he should know the design of the ship as to those points which affect him as the navigator; and, knowing the intention of the designer, he will be able to follow out the design, and by careful observation will afford data for investigation and future application.

We might by such means soon arrive at an understanding as to what is meant by a "good sea-boat" or a "bad sea-boat," and what are really "sea-going" qualities.

There is no modern work with which we are acquainted which attempts to define what are the elements which should obtain in a sea-going ship; we are, therefore, compelled to refer to that work which some modern writers have termed obsolete, but which, although dating back to the latter part of the last century, is the work of a genuine naval architect, and we know of none more likely to afford the student a more extended view of the principles of naval architecture;—we allude to Chapman's work, for a perusal of which, says the late Dr. Inman, "the student will certainly thereby acquire true notions on the nature, extent, and real difficulties of the subject; and what is equally important, he will be put on his guard against the many erroneous conclusions that persons not thoroughly conversant with it are apt to fall into."

The principal good qualities I conceive to be (says Chapman)—

1st.—That a ship with a certain draught of water should be able to contain and carry a determinate lading.

2nd.—That it should have a sufficient and determinate stability.

3rd.—That it should be easy at sea, or its rolling and pitching not too quick.

4th.—That it should sail well before the wind, and close to the wind, and work well to windward.

5th.—That it should not be too ardent, and yet come easily about.

Now these are definitions which leave the matter too much to the empiric.

1st.—We should have defined within what limits can a certain amount of cargo be carried at a certain speed, by wind and by steam.

2nd.—What is the maximum angle of rolling which a ship should perform as well as the maximum angle of pitching and scending?

3rd.—At what speed should a certain amount of cargo be carried, contained within certain limits, before the wind?

4th.—Within how many points of the wind should such a vessel sail, and what is considered "working well to windward?"

5th.—Is, we think, sufficiently explicit.

Now these few requirements do not contain all the elements of a good "sea-going ship," except, perhaps, as far as merchant-vessels are concerned; but in vessels for war there are, doubtless, other important elements, and we think it comes within the province of the naval officer to say what are the essential elements which should exist in the machine of war with which he has to defend our coasts and commerce. Here, then, is a field for observation of the greatest interest and utmost importance for the naval officer, and we must consider the naval architect completely "at sea" until it is a settled point where the centre of gravity of a ship in relation to its length and depth or height should be.

It is thus for the sailor to say what are sea-going qualities, and for the naval architect to discover what should be the relative position of the centre of gravity of a ship.

ART. X.—*Naval Architecture: Its Rise, Progress, and Present State.* A Lecture delivered by CHARLES F. HENWOOD, Esq., N.A., at Blackheath, on the 23rd October, 1865.

No apology, I trust, is needed for introducing the subject of naval architecture to your notice—a subject of vital national importance and great mercantile interest. Ruskin, in his "Stones of Venice," says of Mr. Ferguson, "that he perceives a kind of beauty in a ship," while he (Mr. Ruskin) "has no manner of doubt that a ship is one of the loveliest things man ever made, and one of the noblest." There are few, I take it, unprepared to endorse Mr. Ruskin's words; for one has only to look at our fleets of war-vessels, at the efforts of our gigantic steam navigation companies, at our ocean fleets of merchantmen, and, last but not least, at our fleets of yachts, to discover, not beauty merely, but beauty diversified and in various forms. The love of the sea is exemplified by our yachtsmen and by those who quit both town and country to enjoy the refreshing breezes and pure air of the sea, and to try the salutary effects of its waters.

In those months when storms are rare and of short duration, the magnificent appearance of a sea so long accustomed to peace holds out strong inducements to water excursions. At first timid individuals venture but a short distance from the shore, and that they only think of doing during a calm in the middle of a serene summer's day. Apprehensions of danger are overcome in proportion as the circumstances which give rise to them become familiar, without bringing trouble with them.

People soon experience an unaccountable charm in being tossed to and fro by a wave; so uncertain in its effect as never wholly to remove the possibility of danger, yet for the moment carrying them safely over its crystal waters. At last bold dispositions—men whom nature has gifted with a strong imagination or a firm resolution—are tempted to risk themselves by the sight of an ocean which loses itself beyond an extensive horizon, and opens a free course to every continent.

Thus it is that thousands acquire a fondness for the sea, and give themselves up to naval enterprise, having war, commerce, or science for their object, and return to their country with trophies, wealth, or knowledge,—worthy achievements of the sea.

The "wooden walls of Old England" have been sung as England's best bulwarks, but I doubt whether too much praise has not been bestowed on them, because the whole credit has been in a sense due to the pluck and indomitable courage of our noble sailors. It is well known that the "wooden walls" of Old England, within which our sailors fought the battles of their country, were inferior in every respect to the "wooden walls" they had to contend against; indeed, it is the case, that the captured ships of the enemy have at different periods furnished models for the development of the principles of naval architecture in the Royal Navy. To be particular, it happened during the old French revolutionary war, and during the American war of 1812 it was evident that both in ships and guns we were behindhand with our cousins. Were war again to break out (which God forbid!) we should assuredly find ourselves in much the same relative position of inferiority as existed fifty and seventy years ago.

It was well said by Sir Walter Raleigh, in the reign of Elizabeth, that "whosoever commands the sea commands trade, and whosoever commands the trade of the world commands the riches of the world, and consequently the world itself;" but, in the words of an eminent writer on naval architecture (the late Mr. Creuze), who expresses sentiments of singular appropriateness to the present time, "The time has passed by in which the command of the seas either can or ought to be maintained in the spirit in which Sir Walter Raleigh framed this aphorism. Still the principle it is intended to enforce is as essential to the well-being of England now as then." He continues, "We rejoice at the liberality of international communication, and at the political relations which distinguish the present age. We do more. We fervently hope that the same spirit may increase even until all national divisions shall vanish before it. Yet we cannot but remember that it is with nations as with individuals. Interests may clash, quarrels may arise, and the friendships and kindly feelings of to-day may be succeeded by the dissensions and feuds of to-morrow; therefore, even in the midst of a peace unexampled for its heartiness and for the good faith which apparently pervades the councils of the nations of Europe, we cannot with wisdom neglect those means of defence which have hitherto preserved our land inviolate."

It is only now and then that we find it necessary to be soldiers; but the sea is our element, and it is there that we should find ourselves the strongest. A Frenchman (M. Michel Chevalier) who visited England a few years since, thus speaks of us and our maritime position. "It is commerce," he says, "which has made this island, lost amidst the mists of the ocean, the warehouse of the civilised world. England, in a word, is a surprising and marvellous beehive. England, by her intelligence, her perseverance, her knowledge, and her genius, gives scope to capital which she has steadily accumulated, and which is one of her most powerful levers of war, as it is for the enterprises of peace. Being the first commercial power of the world, and all her commerce being necessarily over the sea, she has recognised for some time back that which common sense indicates, that for her the seas must be free. During a succession of centuries, to be the better assured of the free use of this element, she affected its empire: at the present time, in deference to a more equitable sentiment of public law, she has abdicated these absolute pretensions; and recently, by the Treaty of Paris, spontaneously recognised the rights of neutrals, which she victoriously resisted doing so long as they struggled to obtain this recognition by force. But concessions to modern ideas have in practice a limit which it is not difficult to mark. A State which, at the time he wrote, sent abroad annually £120,000,000 worth, and from the latest returns for 1864, £142,317,384 worth of the products of her manufacturing industry, without counting a mass of foreign merchandise in respect to which she acts as an intermediate agent—such a nation cannot do without the freedom of the seas. A State which receives from beyond the ocean, for the food of its population, 10,000,000 quarters of grain, without speaking of the innumerable cargoes of live stock and salted meat, millions of quintals of sugar, tea, coffee, &c.—such a State is bound to inquire every morning if something does not appear to be in preparation elsewhere which may some day acquire dominion of the seas."

"England would be gravely compromised, even in the conditions of her existence, the day when a possible coalition between the maritime powers would render it possible to oppose her fleets with fleets superior or even equal. It is for her a question of life or death." Lord Palmerston has also said, "If ever we lose the command of the sea, what becomes of the country?" Means of defence should therefore always have our best attention; but obviously, if we wish to maintain pre-eminence on the sea, and with it the trade and riches of the world, we must not look only to our fleets of war and guns, but to the unerring principles of science, in which alone a full and safe measure of completeness and perfectability is to be found. Whatever may have been said by some ill-advised and rash assertors to the contrary, a ship is the most extraordinary and wonderful machine that owes its existence to the agency of man. There is scarcely an art or science which is not in some way or other connected with it, or which may not be made useful to its construction. There is no depth of study which may not be made available to its theory, no mechanism more ingenious than that required in its practice.

I shall presently demonstrate the benefits which would be derived from science, more intimately and generally applied to the construction of our merchant navy; what it would save in wear and tear of ship and gear, in risk of loss at sea, what gain in greater speed, better stowage, and in lessening the risk of shipwreck. Moreover, I am not sure whether I may not further commit myself to promising an alleviation of that greatest of all pests, sea-sickness.

The naval architect is chiefly responsible for the improvement of our ships; he should provide ships ready for the hands of those who are to navigate them. It is the ship with her masts and sails (and sometimes engines) adapted for her, and her stores and their stowage arranged, which is required from him. That these objects may be all achieved and perfect in their kind, not only is the most profound theoretic knowledge required, and that too in several sciences; but there must be a vast fund of sound practical experience based on that theoretical knowledge; and let it be remembered that the excitement of emulation is deadened in the mere copyist, and one of the chief incentives to improvement lost in the servile office of imitation. But the naval architect must have the co-operation of the merchant shipowner and the sailor, and in steam navigation that of the engineer. The sailor, to fulfil his responsibilities, must, in addition to a knowledge of his profession as a navigator, be acquainted with the general principles of science as applied to naval architecture, especially in the disposition and stowage of cargo; because a ship may be constructed and built as ships ought to and yet if the cargo is not properly disposed and stowed, all the evils of a bad ship may positively be encountered throughout the voyage.

As all know, it is the part of the engineer to supply the most powerful and effective means of propulsion, yet of the least possible weight, to occupy the least possible space, and to consume the smallest possible quantity of fuel.

Naval architecture, strictly speaking, is a new science. The art (or mystery, as it has been called) of Shipbuilding dates back to the Phœnicians, if not to that of Noah; but it is not my intention now to enlarge on the varied views of maritime nations as to what a ship ought to be. Necessity was their great preceptor, and supplied them in a rough and ready manner with floating fabrics.

In England naval architecture as a science dates from the early part of the present century. The great superiority of the French ships over those of the English at the close of the last century suggesting inquiry into the inferiority; and although a good deal of attention appears to have been attracted to the subject, it failed in yielding satisfactory results. The reason was, the speculative ideas of men, although of undoubted sense and judgment, yet uninformed as to principles, were taken as the rule of guidance. In France, on the contrary, science in its true acceptation was employed, and some of the greatest mathematicians of that country devoted themselves to the improvement of their country's shipping.

Several real attempts, however, appear to have been made in England to improve the state of knowledge on this most important subject. One of these was the formation of a society in 1791 for the improvement of naval architecture. Again, in 1811 there was the foundation of the School of Naval Architecture at the Royal Naval College at Portsmouth. Students in the latter case were admitted by competitive examination, and the course of study was singularly well chosen. The students were engaged in acquiring under competent professors the mathematical sciences with practical shipbuilding and construction from scientific deductions; and their studies finished, they were sent to sea as supernumerary officers in an experimental squadron to report on the performances of the vessels in which they sailed. They thus gained most important information and actual experience of the elements with which ships have to contend. But well chosen as the studies were, it would appear that the naval authorities of the time became afraid of the power of science. Reversing the proverb, they determined that "power is knowledge," and abolished the school in 1832; happily, however, for the country, not before forty-two pupils had passed. And here observe that, notwithstanding the large sums of public money expended in obtaining those thoroughly trained naval architects, such was the official opposition to science, that for nearly half a century no advantage was taken of their knowledge and experience. Indeed, when they were alluded to, it was usual for the authorities to assert from their places in Parliament "that these young men (men between forty and fifty years of age), though gentlemen and men of education, wanted experience, and therefore could not be promoted." The greater number were kept in subordinate positions in the Royal Dockyards. I will here quote an extract from a paper on the education of naval architects, by

Mr. Scott Russell. He says—"It was not until 1842 that they (the members of the School of Naval Architecture) were permitted to exercise their vocation of even suggesting, advising, and making new designs for new ships, and although they had not been allowed to acquire any previous experience by designing ships that were actually built, their vessels obtained with certainty and precision every condition for which they were designed. I am warranted, therefore (Mr. Scott Russell continues), in saying the School of Naval Architecture fulfilled its intentions; that its persecuted and neglected pupils did full justice to their education, and after the empiricism which oppressed and displaced them had broken itself to pieces against the laws of nature, these despised pupils were found to be the only people capable of restoring naval design to the rank of a science of certainty and precision; and at a critical moment, when the whole navy of England had to be transformed from a sailing fleet into a steam fleet, it was most fortunate that England was able to lay its hands on a class of men of good education and matured minds, whom the Admiralty were compelled by public opinion, and much against their own will, to employ, and in whose hands the transformation was speedily, effectually, and creditably accomplished."

That the best results have eventually followed the establishment of the School of Naval Architecture in 1811 is now generally acknowledged. Our noble fleet of *Warriors*, from the designs of a member of the School, have proved the advantage of designing from scientific deductions, as distinguished from mere speculative *ideas*. In a word, the members of the School were the advance guard of science—its "forlorn hope." The writings of the members are chiefly contained in a work edited by two of their number, which was published periodically from 1826 to 1832, when it was suppressed by official power, it being intimated by authority to the editors that its continued publication would retard their promotion. It is much to be regretted that they should have succumbed to official oppression. Others of the School, however, still fought on in the cause of science for their country's benefit, and reaped the consequences threatened in the case of the editors of the papers. They fought in a noble cause, and laid the foundation of permanent improvement in the "main artery" of our national existence.

As further showing the official antagonism to science and inventions, I may recur to the screw-propeller, which has effected almost as great a change on the ocean as the locomotive on the land. The screw-propeller was actually introduced by Mr. F. P. Smith, and to him, doubtless, the prize has justly been awarded, for I am of opinion that although the merit of an invention belongs justly to the original inventor or discoverer, yet if he fail, from whatever cause, the greater credit and greater honour are due to the man who, in spite of every opposition and by indomitable perseverance, risking fortune and often life too, succeeds in making manifest the invention or discovery for the benefit of his country. Such a man, I believe, is Mr. F. P. Smith (the present Curator of the Patent Museum at South Kensington), but the invention or discovery of the screw-propeller appears to have been made by Mr. Robert Wilson in 1812, who states that the screw-propeller might have been adopted in the navy as early as 1827 to the saving of millions of the public money.

Our navy consists now of 357 screw vessels afloat; our mercantile navy consists of 2,401 screw vessels.

In 1827, and again in 1833, Mr. Wilson submitted his invention to the naval authorities, but they rejected it without even a trial. Through want of means and its being so condemned, Mr. Wilson was compelled to give up the further prosecution of his invention. In 1837, Mr. F. P. Smith, keeping clear of the naval authorities, in the words of Mr. Bourne, "carried his vessel to sea, and showed by repeated experiments that the objections said to be entertained did not exist." It is curious to note that the abolishing of the School of Naval Architecture, that the official power used to suppress the publication on the science of naval architecture, and that the condemnation of the invention of the screw-propeller, were all three performed by the same Naval Administration, and within the space of twelve months.

Our naval administrative system has always been an obstruction to scientific progress, and nothing but public opinion has ever moved it. It would be well for the country were the entire system swept away and replaced by one more in accordance with the advancement of the age. With reference to this subject, Admiral Halsted, in a letter to the *Daily News*, speaks thus strongly:—"Would it not (says he) be just to subject a practically irresponsible power based on the demoralising principles of party and family interest and support, and daily assuring the proprietor instead of faithfully enacting the steward?" He further says that "M. Raymond, who has written a candid and excellent work on the navies of England and France, and while he attributes all our success to the maritime genius of the nation speaks thus of the

English Admiralty"—"Nous croyons pouvoir dire en tout securité de conscience que c'est une organisation administrative aussi peu rationelle qui existe en aucun pays." M. Raymond adds that a French Admiral, full of admiration of our naval glories, said to him, with reference to the same institution, "C'est une vieille commère qui est en arrière de deux cents ans sur le plus modeste constructeur de son pays."

Naval architecture, as a science, being so recent in its origin, it is not surprising that it has been almost exclusively in the hands of the members of the late School of Naval Architecture, and as the members of the School had seldom anything to do with the mercantile marine, the science has made but an inadequate advancement in our merchant shipping, and consequently it has been constructed to a great extent from speculative ideas merely, or, as it has been termed, the "rule of thumb," and not from scientific deductions.

What have been considered good vessels are, to a great extent, happy accidents; not that I deny that great improvement has taken place in our merchant ships within the last twenty years, but I maintain such improvements have been the results of science, or of the observation of vessels which have been designed by men of science. Creuze observes:—

"A most unphilosophical mode of reasoning is very generally made use of in the question of the application of the exact sciences to naval architecture. It is assumed that since ships possessing more than an average of good qualities have been produced without abstract scientific study, the exact sciences need not be made available for the advancement of naval architecture, the fact being placed quite out of the consideration, that the results of observations on ships designed by men of science are really the results of science, and that if the observations were made by persons competent to the task, these results would be onward steps in the progress of improvement.

"It has been wisely said that there are more false facts in the world than false theories; the reason is evident: the correctness of a fact is totally dependent on the competency of the observer, and how very few, even among those whose minds have been trained to habits of thought, are equal to the task of discriminating fact from fallacy.

"A great error, which hinders to some extent the advancement of science, is the assumption that the theory of naval architecture is already perfected, instead of merely being capable of being perfected. It should always be remembered that generally in every science a perfect theory is the result of the perfection of the science, rather than that the perfection of the science is the result of the theory."

Having thus briefly sketched the rise and progress of naval architecture in England, I shall now speak of its present state; but before doing so, it will not be out of place to glance at an establishment to which the country may look forward to its producing the happiest results—I mean the Institution of Naval Architects. The institution was inaugurated by its President, Sir John Pakington, in 1860, and in his address he says, "The present period is remarkable; the introduction of the power of steam has altogether altered the principles (practice?) of naval architecture, and we must bear in mind that France, Russia, the United States, and England may all be said to be starting fair in the great race of competition, and I take it that if I were to inquire in one phrase, What is the real object of this institution? the answer would be, 'It is to take care, as we are bound as Englishmen to take care, that beyond all question England shall win that race.'" "The means, the chief means, I imagine," he continues, "by which we must seek to achieve that success is by taking care that by the exercise of the skill of our scientific men, our men of war and our merchant ships shall be so constructed as to carry on the one hand either heavy guns and large crews, or on the other, large cargoes, and still derive all the benefit which they ought to derive from carrying steam-engines to propel them."

NUMBER and TONNAGE of VESSELS built in the United Kingdom and in the British Possessions in the year 1864.

	Sailing Vessels.				Steam Vessels.			
	Timber.		Iron.		Timber.		Iron.	
	Vessels	Tons.	Vessels	Tons.	Vessels	Tons.	Vessels	Tons.
United Kingdom..	713	146,783	154	125,716	32	2,393	342	156,981
British Possessions	785	206,029	—	—	28	7,027	5	289
	1,498	352,812	154	125,176	60	9,420	347	157,270
Total for the United Kingdom and British Possessions......							2,059	645,218

of the estimated total cost of £17,450,000 sterling.

It may appear presumptuous to repeat that the majority of our merchant vessels are constructed not from scientific deductions, but from inductions by a tedious course of failure, analogy, and ideas, but such is the case; nor is it surprising when it is remembered that the introduction of the science of Naval Architecture is of so recent a date, and that it has been so long kept under "pains and penalties" by our naval administrators.

As a proof of the correctness of this statement, I may mention the following serious errors which have been committed in vessels within the last three years. Vessels have been launched and found to exceed the contemplated draught of water to such an extent that it has been necessary in remedying the error to haul the ships up, or place them in dry dock, cut them asunder, and lengthen them at great expense and delay. Again, vessels have been launched and found to float too deeply by the head, and have had to be trimmed with ballast, and in some cases they have even had to be cut asunder and lengthened. These are blunders which would have been prevented by the application of the simplest rules of science.

Let us now look at construction from experience (which is induction by a tedious course of failure) and analogy, and also at construction from scientific principles, and deductions from them.

Experience or facts are of importance only (as I before stated) as they are correct and true, and the various differences in experiences will prove how fallacious and untrustworthy they may be. From experience men have said—and men of ability, too—that to make a vessel "stable" (*i.e.* stiff and upright in the water) the guns should be run out: this they have proved by actual experiment. Again, men have stated that to make a vessel "stable" the guns should be run in: this also they have proved by actual experiment. Now, is it to be expected that both are right? But science discovers that both up to a certain point are right, and that benefit would result in each of these cases by the operation of the two methods. Again, men of experience have stated a rising floor gives the best ship; on the other hand, it has been stated that a good ship must be a flat-floored ship. Both make the statement from experience and observation, and there is no doubt that in each of these cases both observations were correct, but the conclusions wrong, in attributing the effect to the wrong cause. Again, great length has been found from experience to obtain great speed, and therefore it has been concluded that to obtain great speed, great length is essential. Now, to a certain extent this latter fact is correct, but to a limited extent only, for that favourable element which is obtained by extreme length would be obtained by a vessel of good proportional length if constructed in accordance with the laws of Dynamics. I will explain in general terms my meaning, and in speaking of speed I wish it to be noted that it is meant not the speed obtained by driving a sharp-ended box by a powerful engine through the water in a river or mill-pond, but a ship and sea-going speed.

Now, the great benefit derived by a long vessel, in addition to what is called a fine entrance or bow, is that a long vessel is not so violent in its pitching motion as a short vessel, and consequently goes more steadily through the water, with a less expenditure of power and greater speed. But great length is attended with very serious disadvantages as to sea-going qualities, besides excessive and needless expense in first cost, and subsequent wear and tear. I might enumerate many similar cases, discoveries by a tedious course of failure—some correct in part, others entirely fallacious as to general principles, but true as to certain special cases. Thus much, then, as to construction by experience from a tedious and expensive course of failure.

Analogy, or perhaps more properly resemblance, has had its disciples, and the animal creation has afforded types and given ideas to the analogist. The cod fish has been the great favourite, and till recently the cod's head was the type for the bow or fore-part of the ship, and the tail the type for the stern or after end of the ship. Now, the opposite has been found by experience to be the best, and the type now is tail for bow, and head for stern. Various other creatures have silently given ideas, but I think analogism has culminated in that egregious piece of folly being perpetrated at Millwall—I mean what has been called the "cigar *ship*," costing, I believe, somewhere about £100,000.

Construction on scientific principles does not exclude experience, but sifts it by the laws of science, reconciles what experience cannot reconcile, and presents a basis to start from. The science of *mechanics* fills an important place in the theory of naval architecture, but the term mechanics is popularly considered to represent the mechanical powers only. The science of mechanics is divided by Newton into *practical* and *rational*, the former treating of the mechanical powers and of their various combinations, the latter or rational mechanics comprehending the whole theory and doctrine of forces, with the motions and effects produced by them. The part of mechanics which treats of the weight, gravity, and equilibrium of bodies and powers is called *statics*, and that part which treats of weights in motion is called *dynamics;* so, when fluids instead of solids are the subjects of investigation, that branch which treats of their equilibrium, weight, pressure, &c., is called *hydrostatics*, and that which treats of their motion, &c., *hydrodynamics*. The various motions performed by a ship are distinguished by technical terms, such as *pitching*, *'scending*, *rolling*, *lurching*, and *yawing*. Pitching and 'scending are longitudinal motions, rolling a lateral motion, lurching and yawing a combination of longitudinal and lateral motions; but the most important and most injurious of these is *pitching*. Rolling has had the most attention bestowed upon it by mathematicians and naval architects, and the laws which govern it are now well known, so that no excuse can be made if a ship be built wanting in that important element of proper lateral stability. But the same amount of attention has not hitherto been bestowed on pitching and 'scending, because perhaps it has been considered an unimportant subject and is a far more difficult problem than lateral stability or rolling.

Lurching and yawing being produced by a combination of the longitudinal and lateral motions, if these two latter be reduced to a minimum, they will follow suit.

Pitching is the most violent action to which a ship is subjected, and the most injurious both to the connection between the parts of her structure and the velocity of her sailing or speed. It has been defined to be "the longitudinal motion, caused by the variable support afforded to the body (or ship) by the waves as the vessel passes over them, and by the constant action of the gravity of the unsupported part of the body to recover the state of equilibrium which before the commencement of the motion had existed between it and the buoyancy of the fluid." Now, this definition makes it a compound problem of dynamics and hydrodynamics, and in its hydrodynamical aspect it has most generally been considered. But there is no part of mechanics the true theory of which we are so little acquainted with as the science of *hydrodynamics*. The greatest mathematicians have been forced to yield to the numerous difficulties of these researches, and to confess that the methods so successfully followed in the mechanics of solid bodies do not afford any conclusions with respect to fluids but such as are too general and uncertain for the greater number of particular cases, so that however interesting the investigation of hydrodynamics in its relation to naval architecture may be, it is practically of little service.

The second part is vague, but this definition appears to have been generally accepted.

Pitching, indeed, is one of the most important elements to be attended to in constructing a ship, either for war or mercantile purposes; its neglect, or ignorance as to the laws which govern it, or their application, is unjustifiable. Pitching, in its strictest sense, is caused by the absence of the application of the laws of dynamics, and is strictly a dynamical problem, and as such is brought within the control of the laws of science. Its acceptance as a hydrodynamical problem has, I believe, been the reason why but little attention has been bestowed on the subject. In 1830, however, my father, a member of the late School of Naval Architecture, investigated the subject, and propounded a new theory of construction which I have designated by the term "Dynamical theory," by which pitching would be reduced to a minimum. I have since continued the investigation and practised the theory in the vessels designed and built by me within the last eight years with success, which warrants me in stating that pitching (in its strictest sense) should no longer exist. Now, if pitching were not to exist in a ship, the advantages would be that a most "stable fighting platform" would obtain in a war-vessel. And all vessels constructed on the longitudinal "Dynamical theory" or principle will obtain those desirable advantages I enumerated at the commencement—viz., the saving of wear and tear of ship and gear, less risk of loss at sea, greater speed, better stowage, less damage to cargo, less risk of shipwreck and loss of life, and an alleviation of that greatest of all pests, sea-sickness. In addition a vessel may be built lighter, and therefore would carry more cargo, long voyages would be performed quicker and cheaper, and in our narrow channel, passenger boats would be more comfortable.

The following table shows the number and tonnage of sailing and steam vessels registered in Great Britain and in the colonies of the United Kingdom on the 31st December, 1864:—

	Sailing Vessels.				Steam Vessels.			
	Of and under 50 Tons.		Above 50 Tons.		Of and under 50 Tons.		Above 50 Tons.	
	Vessels	Tons.	Vessels	Tons.	Vessels	Tons.	Vessels	Tons.
Great Britain	9,817	303,356	16,325	4,626,863	926	21,961	1,564	675,320
Colonies..	5,717	156,625	5,992	1,232,015	112	3,224	325	66,623
Total...	15,534	459,981	22,317	5,858,878	1,038	25,185	1,889	741,943
Total for Great Britain and the Colonies, Steam and Sailing Vessels							40,778	7,085,987

of the total value of £195,000,000 sterling.

That so vast an amount of capital should be invested in floating fabrics upon which so little attention has been thought necessary, and should merely be exemplifications of ideas, views, and experience rather than of the laws of science, may well be considered a marvel; for there is no object upon which more varied or more extended knowledge may be advantageously bestowed.

A citizen of London may be naturally proud of the commercial fleets which daily arrive and depart, the latter exporting the produce of national industry, the former importing foreign productions or treasures, fulfilling the prediction of Pope in his early poem, "Windsor Forest." He says—

> The time shall come when, free as waves and wind,
> Unbounded Thames shall flow for all mankind,
> Whole nations enter on each swelling tide,
> And seas but join the regions they divide.
> Earth's distant ends our glory shall behold,
> And the new world launch forth to seek the old.

He cannot, indeed, contemplate this immense scene of action without confessing that his native city owes its wealth and greatness to commerce and the sovereignty of the seas.

The following table shows the number and tonnage of British and foreign vessels that entered and cleared from the port of London between the 31st December, 1863, and 31st December, 1864:—

SAILING VESSELS.

Inwards.				Outwards.			
British.		Foreign.		British.		Foreign.	
Vessels.	Tons.	Vessels.	Tons.	Vessels.	Tons.	Vessels.	Tons.
4,862	1,457,268	3,598	878,171	2,593	930,003	2,781	664,668
STEAM VESSELS.							
2,232	839,145	514	185,198	1,823	648,166	499	178,584

	Vessels.	Tons.
Total of Steam and Sailing Vessels entered Inwards......	11,206	3,359,782
,, ,, ,, Outwards....	7,696	2,421,421

This is little more than one-tenth of the total number of vessels entered inwards and cleared outwards from all the ports of the United Kingdom.

Satisfactory as this may be, we must not forget the reverse side of the picture—shipwreck and consequent loss of life.

The *Times*, in September last, in reference to this subject, says—"Gratifying as the fact may be, that our commerce is year by year expanding itself by many thousands of tons of shipping, it is a lamentable and mortifying truth that the advance of our science and skill does not keep pace with this expansion, in diminishing the number of wrecks that every year play out their tragedy on our shores. It is true that no man can contend with the elements; it is inevitable that shipwrecks will occur from various causes in our seas and on our coasts, but we nevertheless maintain firmly that skill and precaution can successfully battle with the most fearful storms to a large extent."

The official return for the twelve months ending December, 1863, gives, for the United Kingdom only, casualties 1,741, resulting in the total wreck of 639 sailing vessels of the gross tonnage of 164,659 tons, and 29 steam vessels of the gross tonnage of 11,104 tons, of the estimated value of £4,505,095 sterling, and the imminent risk of 5,716 lives, resulting in the loss of 620 lives, whose value cannot be computed; and during the present year, from January up to 23rd of last month, the shipwrecks and collisions reported are 1,513; the number of lives lost I have not yet been able to ascertain. "Yet," says the *Standard*, "there is nothing in creation more beautiful and magnificent than this same ruthless and restless ocean. Thousands have gazed on it with unceasing delight from the cliffs and beaches of the British Isles during the hot months of the now fast-fading season. Englishmen, and Englishwomen too, love the sea as much as the Swiss are said to love their mountains, and a perpetual banishment from the sea-shore is a deprivation to which no true-born Briton will submit, even if the indulgence can go no farther than the hasty and imperfect glance known on the Brighton line by the designation of 'eight hours at the sea-side.'

"After the wonderful calm of the past summer we know the usual change will come, and that ere long the tempests will again howl around these sea-girt isles. When the days grow short and the gloom of winter beetles round the cliffs, when the waves have ceased to sparkle beneath the sunny sky, when the gay crowds no longer gather on the shingly shores and ribbed sea-sands of our fashionable coast towns, there will be stern work to do in battling with the billows and the gale on the coast of Britain. Guns will be heard booming to the westward from some big ship which has struck the reef, rockets will dart up in the sky where the hapless collier has run aground, anxious eyes will peer through the mist, to see where the white surf is leaping over the black hull, and brave men will hurry down to the strand to man the boat which alone can live in such a sea, and by which alone the waves can be robbed of their accustomed prey. Despite all that heroism and humanity can accomplish, there will yet be many a swollen corpse tossed up amid the torn seaweed and the fragments of a broken ship; and when summer once more comes with its gentle zephyrs and its glittering seas, there will be many a widow and orphan in this kingdom to lament the storms of the past winter. All that can be asked is this, that philanthropy shall open its hand widely to mitigate the horrors of shipwreck by providing the means of escape, and that human skill and foresight shall be vigorously exercised to eliminate every avoidable risk from among the 'perils of the sea;'" and in addition I may say, let us see that we avail ourselves of the advantages and benefits which science, applied more intimately and generally in the designing of our immense merchant navy, will procure in lessening these casualties.

Naval architecture and naval tactics (says another writer on naval architecture) have ever derived their greatest advantages and improvements from men of science, and not from mere practitioners. We must not, then, look for improving and perfecting our ships to men who may bring forward some geometrical or mechanical series of curved lines for a ship's body, for this has been done many times, and may at all times be performed by the mere dabbler in the art;

or to those who, regardless of any rules, build ships by what they call the eye, for there are enough of these, and when either asked for reasons for any particular construction assume mysticism, and would appear wise by saying nothing. Certainly from no such men are we to hope for improvement in a science pregnant with difficulties to surmount, which seems to exceed the force of the human understanding. But let us look for the advancement of naval architecture to those who unite the theory with the practice, who are patient observers of the physical facts which experience brings to view, and have sufficient science to account for these either by laws long established, or if not, to endeavour to discover new ones. "Every man who can in any way add to the security with which the sea may be navigated is as much bound to diffuse such knowledge as he would be to save a drowning man from the waters; whether the additional security be attained by the improvement of the chart which is the guide to navigation, or the chronometer and sextant which render that guide available, or finally of the ship itself. The additional security is a boon to mankind, and the promulgator or inventor of the means by which it is attained is truly a benefactor to his species, because in proportion as the means and aids of navigation are perfected its dangers are diminished, and in proportion as the knowledge of the methods for improving them is diffused, so is the whole family of man benefited, and the natural state of society, which must be presumed to be a state of peace and good will, ameliorated."

I have now only to return you my most sincere thanks for the kind attention you have given me this evening, and would sincerely beg your indulgence for the many faults of an amateur lecturer. I shall feel well rewarded if I have, by this collection of notes and jottings of my leisure hours, created an interest in this most beautiful and most important science; and when I shall have the pleasure of again appearing before you, the tediousness and dryness which naturally attends the introduction of a new subject will be dispensed with. In my remarks on Naval Administration I wish it to be particularly understood that the objection is against the obsolete and effete system which the present Right Honourable Secretary of the Admiralty so vigorously condemned in his speech in 1859, and which all real lovers of their country, conversant with the subject, desire to see reformed, and is not in any way connected with the gentlemen of the highest honour, ability, and integrity, who have at various times been associated with the system as by law established.

ART. XI.—*Remarks on the Mackay Gun.*

THE Mackay Gun promises to be the long-desired naval arm (Plate 2, Fig. 1); without any sacrifice of the long range, and area of destruction,—desiderata which are respectively understood to be the characteristics of the Whitworth and the Armstrong. The Whitworth, with its small bore, gives great range; but also with inferior area of destruction. The Armstrong, with its large bore, gives great area of destruction, but also with uncertainty of flight, from the imperfection of the studs in the muzzle-loaders, and the stripping of the lead coating in the breech-loaders. The Mackay gun presents a combination of the goodness of the Armstrong and the Whitworth, with qualities peculiar to itself; one of those qualities being perfect adaptation for the hasty and rapid firing essential to the navy. Let us endeavour to make out these statements to the satisfaction of the reader; and afterwards to supply additional information about the gun and its requirements for adoption in the navy.

The barrel of the Mackay gun presents a series of grooves of varying breadth and depth; differing chiefly from other grooves in the twist which the Mackay grooves take. But let us not anticipate. The peculiarity of the barrel of the Mackay gun is not solely in the grooves; there are various other peculiarities. One is that the projectiles enter the barrel loosely and come out loosely, with no mechanical fit as in the Whitworth, no shunting as in the Armstrong muzzle-loader, and no exclusion of air or windage as in the Armstrong breech-loader. The barrel of the Mackay gun, therefore, admits of easy loading and easy firing. There is no jamming of the Mackay projectiles from bad gauging at the arsenal, nor from fouling of the barrel after firing. Mr. Mackay is, we believe, prepared to fire 20,000 continuous rounds from the same gun, using only a dry brush. No British ship of war armed with Mackay guns would ever haul down its flag from the jamming of projectiles in the barrel: because such jamming could not possibly occur. The same cannot be said of any other rifled gun known to the service or the public.

Another peculiarity of the Mackay barrel presents itself as a sequence to the windage and the grooves. It is the admission of the atmosphere to the charge, and the perfect combustion of the charge by the admission of the atmosphere. The Mackay charge is burned—thoroughly burned; while the inability to burn their charges is one of the generally admitted difficulties of the Whitworth and the Armstrong guns. The perfect combustion of the Mackay charge accounts to some extent for the extraordinary velocity of the Mackay shot; but in a naval point of view it attains an end of immense importance. *It spins round shot, and spinning round shot have a certainty and accuracy of ricochet flight on water, absolutely unattainable by long shot.* A spinning long shot in ricochet firing on the water may rise into the air, descend to the bottom, or turn to the right or left: it is erratic. But a spinning round shot will infallibly strike its object, if the gun has been truly laid. On the Mackay system, the old cast-iron 68lb. of the navy can be made arms of accuracy and power, and can be adapted if required to sustain the strain of continuous firing with 30lb. charges, 16lb. being the present charge.

So much, then, for the hasty and rapid firing which is essential to naval warfare. Let us next speak of the combination of the Mackay gun of the good qualities of the Armstrong and Whitworth. The Whitworth gives great range, but effects not so much mischief as the Armstrong. The Armstrong effects great mischief with less uniform precision. What, then, does the Mackay gun do? We cannot answer better than by turning to the practice of the Mackay gun at Shoeburyness.

PRACTICE with the "MACKAY" 12-Pounder Windage Adaptation GUN and PROJECTILE, under the Program of the ORDNANCE SELECT COMMITTEE, at SHOEBURYNESS, on the 20th, 22nd, 23rd, and 26th June, 1865:—

Rounds.	Charge, lb	Elevation, Degs.	Time of Flight, Seconds.	Range, Yards.	Deflection.	
					Left, Yards.	Right, Yards.
1	2	5	6·9	2222	......	12·0
2	2	5	6·6	2106	......	7·0
3	2	5	6·6	2070	......	5·8
4	2	5	6·4	2099	......	8·8
5	2	5	6·3	2048	......	4·0
6	2	5	6·6	2000	......	8·6
7	2	5	6·5	2098	......	11·6
8	2	5	6·4	2053	......	12·6
9	2	5	6·3	2078	......	7·2
10	2	5	6·3	2074	......	8·0
11	2	5	6·4	2065	......	11·4
12	2	5	Not obs.	2096	......	11·4
13	2	5	6·4	2098	......	7·4
14	2	5	6·5	2059	......	11·0
15	2	5	6·4	2086	......	7·0
16	2	5	Not obs.	2100	......	4·0
17	2	5	6·4	2091	......	8·0
18	2	5	6·6	2108	......	5·6
19	2	5	6·3	2101	......	7·4
20	2	5	6·5	2070	......	10·0
21	2	10	11·8	3406	......	24·0
22	2	10	11·9	3431	......	25·0
23	2	10	11·9	3421	......	29·0
24	2	10	11·9	3446	......	29·6
25	2	10	12·1	3454	......	24·0
26	2	10	Not obs.	3448	......	35·0
27	2	10	11·9	3469	......	30·0
28	2	10	11·6	3363	......	40·0
29	2	10	11·8	3429	......	29·6
30	2	10	11·9	3500	......	33·0
31	2	10	11·7	3391	......	36·0
32	2	10	11·9	3390	......	28·0
33	2	10	12·0	3438	......	35·0
34	2	10	11·8	3409	......	40·0
35	2	10	11·8	3460	......	21·6
36	2	10	11·8	3447	......	32·0
37	2	10	Not obs.	3528	......	33·0
38	2	10	11·9	3450	......	31·0

Rounds.	Charge, ℔	Elevation, Degs.	Time of Flight, Seconds.	Range, Yards.	Deflection.	
					Left, Yards.	Right, Yards.
39	2	10	11·9	3428	......	35·0
40	2	10	11·9	3417	......	31·0
41	2	2	3·1	1092	......	5·2
42	2	2	3·0	1083	......	4·6
43	2	2	3·1	1078	......	2·8
44	2	2	3·3	1090	......	3·4
45	2	2	3·0	1072	......	2·0
46	2	2	2·9	1048	......	5·4
47	2	2	3·0	1064	......	2·4
48	2	2	3·3	1093	......	4·4
49	2	2	3·3	1104	......	4·0
50	2	2	3·2	1075	......	4·2
51	2	5	6·4	2136	......	16·6
52	2	5	6·3	2091	......	7·4
53	2	5	6·4	2082	......	13·4
54	2	5	6·3	2051	......	10·0
55	2	5	6·4	2073	......	9·6
56	2	5	Not obs.	2006	......	12·0
57	2	5	6·4	2112	......	9·8
58	2	5	Not obs.	2086	......	9·0
59	2	5	6·4	2065	......	11·4
60	2	5	6·4	2090	......	11·8
61	1½	5	Not obs.	1918	......	6·0
62	1½	5	6·1	1949	......	7·0
63	1½	5	6·1	1940	......	5·4
64	1½	5	6·2	1944	......	5·0
65	1½	5	6·2	1938	......	9·4
66	1½	5	6·1	1963	......	11·6
67	1½	5	6·2	1917	......	4·8
68	1½	5	Not obs.	1892	......	10·0
69	1½	5	Not obs.	1974	......	9·0
70	1½	5	6·3	1911	......	7·8
71	2	2	3·0	1150	......	3·8
72	2	2	3·2	1108	......	3·6
73	2	2	3·1	1128	......	2·6
74	2	2	3·3	1105	......	3·2
75	2	2	3·1	1106	......	3·6
76	2	2	2·9	1076	......	2·8
77	2	2	3·0	1085	......	4·0
78	2	2	3·2	1104	......	4·0
79	2	2	3·2	1103	......	3·6
80	2	2	Not obs.	1112	......	2·4

Target Firing.

Mackay's Target—9 Feet by 9—1000 yards.

Rounds fired	15
Hits direct	11
Hits after grazing	1
Total hits	12
Misses	3
Total	15

A similar target fired at with the Armstrong gun gave on the same occasion the following results:—

Armstrong's Target—9 Feet by 9—1000 yards.

Rounds fired	15
Hits direct	6
Total hits	6
Misses	9
Total	15

Velocities.

The Mackay velocity was	2,200 feet per second.
The Armstrong is only	1,230 feet per second.
The Service 68-pounder is only	1,500 feet per second.
The Somerset gun is only	1,540 feet per second.
The Frederick gun is only	1,560 feet per second.
The 600-pounder with 90lb. is only	1,760 feet per second.
The 13-inch mortar is only	790 feet per second.

These are results which may stand comparison with any others, whether the Whitworth, Armstrong, Scott, Lynall Thomas, or the French. In short, they are results bearing out what we have stated—namely, that in addition to the peculiar qualities of the Mackay gun, there are in combination all that has been ever claimed by rival artillerists—great range, great precision, and incomparable velocity. Perhaps the best recorded instance of the destructiveness of the Mackay projectiles is that of the firing at the *Agincourt* target on the Crosby sands with steel shot and 30lb. charges, at the regulation range of 200 yards. Five shots were fired, all of which passed through, and the collective fragments stripped from the target weighed about 1¾ tons. (See Plate 1, Figs. 1 and 2.) The shot, after passing through the 5½in. armour-plates, 9in. teak backing, 10in. angle iron, frame and skin of the iron ship, made the following extra ranges:—

No. 1	shot passed	82	yards beyond.
" 2	"	440	"
" 3	"	195	"
" 4	"	1,475	"
" 5	"	384	"

Mr. Mackay's attention, we believe, was turned to ordnance by the appeal to the country of the newspapers for a good service gun. That is now some years ago. Since then Mr. Mackay has laboured assiduously, beginning at the beginning with small arms, and working his way upwards to large calibres. More searching and intelligent inquiries have certainly never been pursued, and the result is the Mackay gun and its projectiles. Every honest man will wish him success; that is, the success of speedy recognition by the authorities; for, after all, the inventions and improvements in ordnance by Englishmen should lead to the arming of England, and not of England's enemies—or rather of those who one day or other may become her enemies.

Summing up, Mr. Mackay accomplishes the spinning or the rotation of projectiles by the elastic gases of the gunpowder in a perfect manner; while rival inventors make no such use of the gases, but in an imperfect manner employ mechanical fit as in the Whitworth, or studs and coating as in the Armstrongs. With the elastic gases Mr. Mackay gets as many full turns as desirable; while with the hard or soft metal bearings it is only possible with safety to get barely half a turn, or at the most three-fourths of a turn. And while the hard metal bearings of other systems wears or tears the guns to pieces, the Mackay elastic gases scarcely subject the gun to strain. The absence of strain in the Mackay gun admits of greater charges, windage favours the combustion of the powder, and the increased spin or rotation of the shot gives the maximum of steadiness in flight, while the better combustion of the powder and its greater quantity yields a velocity surpassing all that has ever been attained.

We extract the following from Mr. Mackay's specification:—

Fire Arms and Ordnance Improvement.—This invention relates first to the manufacture of ordnance, which may also be practically applied to small arms, and is designed for the purpose of discharging elongated projectiles from what is known as a smooth-bore gun; and the improvements consist in the application and use of diagonal grooves formed in the interior surface of the gun at a greater angle than hitherto employed, which are to act as "wintage" grooves, so that the powder and gas passing down such grooves encircling the projectile shall have a longer distance to travel than the projectile, and also to cause the projectile to revolve round its longest axis at a high rotation as it passes down the gun. The projectiles are not required to enter or fit these grooves as in "rifles," but simply to pass down the smooth surface in which the grooves are formed. In the manufacture of the gun I pursue any of the ordinary methods, muzzle or breech loader having smooth bores, and groove them in the following manner:—Take, for instance, a smooth-bore 68-pounder to be grooved at the angle marked A in the diagram, Plate 2, Fig 2, for which the length of the projectile should be about twice the diameter of the bore, but the angle of the groove is to be increased if a heavier projectile be employed, and decreased if a lighter one be used, by which means also the necessary velocity, accuracy, and range is obtained. The diagram, Plate 2, Fig. 2, having been properly tested on the small barrel A[1], I propose to extend the same rule or slight variation thereof to ordnance, showing in the diagram the angle extended to the 68-pounder. I would remark that the aforesaid grooves may either be formed from end to end of the bore or only part way, and that the depth of the grooves may be increased as the angle of the groove increases, and lessened as it is diminished, as the angle of the groove is increased or diminished.

It has been found from practical experiments that the velocity of the projectile, and consequently the striking power, is greatly increased with the same proportion of gunpowder as used for the perfectly smooth bore by the use of the grooves when combined with the method of loading which I shall now proceed to describe.

It consists in the use of wood sawdust, cotton wool, cotton wadding, tow, wool, or other elastic material to be placed between the powder and projectile, which, when the concussion of explosion occurs, causes the projectile to become slightly and easily moved before the full power of the powder acts upon it, which ensures the safety of the gun and diminishes the recoil. The sawdust or cotton wadding may be saturated with oleaginous matter to give lubrication and to prevent it from burning too rapidly, and may be placed in the cartridge-bag between the powder and the projectile, in which instance a circular piece of pasteboard or other material is to be inserted and used to keep them separate, or the wadding may be placed in a separate bag, or the sawdust may be placed at the end of the bag and tied, and the powder placed above it. The cartridge-bag must be made so as to burst when the explosion takes place to allow the sawdust or wadding to encompass the projectile, thus preventing the escape of the gas. By filling the grooves and allowing the projectile to receive the full force of the powder without waste, or the cartridge itself containing the powder may also be made of cotton wadding; this description of gun wadding may also be applied to advantage in the ordinary smooth-bore with spherical projectiles. It has been found that numerous discharges may be effected in this manner without the bore requiring cleaning.

Projectiles.—This invention relates to a novel description and form of elongated projectiles to be employed in ordnance, and is designed for the purpose of diminishing the unsteady movement usual in the flight of elongated projectiles, and also for the purpose of ensuring the projectile striking the object on end—that is, as near as possible in a line with its longitudinal axis.

The improvements consist in so forming or shaping the elongated projectile that a certain length thereof (say, for example, one-third) shall be of less diameter than the remaining two-thirds, which occupies the bore of the gun, the exterior surface of the lesser and larger diameters both being in lines parallel to the axis of the projectile, and the junction between the two varying diameters is formed by a beve or inclined shoulder, and both the ends or terminations of the projectiles are semicircular, the radii of the semicircles being half of either diameter, and the centres thereof being upon the line of axis. In order to balance the projectiles, if desired, from the centre of its length, a small portion of the front semicircles may be removed.

Fig. 3, Plate 2, represents a side view of one of the projectiles, showing the larger diameter A, which bears upon the bore of the gun and its semicircular end, and the lesser diameter B, and its semicircular end, which diameter is consequently somewhat less than the bore. Fig. 4, Plate 2, represents a side view of the projectile, the front end C, or that nearest to the gun, being partially removed in order to balance it if required. I would also remark that hollow "shells" may also be thus formed or shaped on their exterior surface.

In manufacturing the said projectiles when made of wrought metal or steel, the bar of metal is first to be cut off to about the weight and length required, it is then to be hammered or "swaged" when heated (by any heavy hammer) in a horizontal position, the hammer-head and anvil being each formed like half the projectile as a "swage," or the bar may be "swaged" in lengths, for a number of projectiles, and afterwards cut to about the length and weight required; after this it is to be reheated and placed in a vertical die box in the form of vertical half of the projectile, and having an opening at the bottom through which the surplus metal is placed when the hammer or hydraulic pressure is exerted on the upper half of the die box. By this means the metal is densified in proportion to the pressure employed, and when the pressure has been sufficiently great, no further "hardening" is necessary for steel projectiles. When the projectile is thus far advanced, it is cooled as rapidly as possible, and may then be centered in a lathe, and the whole exterior, or the part bearing the bore of the gun, may be polished, in which state it may be heated again and "tempered" or not as may be requisite. When forming these projectiles in cast metal, they may be cast in metallic moulds as usual, the moulds being internally shaped like the exterior of the projectile.

ART. XII.—*The Turret or Central System of Captain Cowper P. Coles, R.N.; its present Phase.*

THE following is the Report of the Committee of Naval Officers, forwarded to the Admiralty in June last—composed of Vice-Admiral the Earl of Lauderdale (Chairman), Rear-Admiral Yelverton, C.B., Captain Caldwell, C.B., Captain Kennedy, C.B., Captain Phillimore; Secretary, Mr. Arthur Price—on the *Advantages of Captain Cowper P. Coles's Central System of Armament;* and also the Report of Admiral

Goldsborough, of the United States Navy, dated Feb. 26, 1864, to the Secretary of the United States Navy. The Committee say:—

"The distinctive advantages of this mode of armament appear to us to be—

"(*a*) That it is the most efficient mode of carrying and working very heavy guns in a sea-way.

"A steadier platform is obtained, from which to fire.

"A gun mounted in a turret is higher out of the water, and, being also in the centre of the ship, can therefore be fought longer and more efficiently in a sea-way than when mounted on the broadside.

"The extent to which the gun can be trained in a turret is only limited by the obstructions on the deck.

"There is also greater facility of training than with broadside guns, as at present fitted.

"When under the fire of musketry the port in the turret can be turned away from the enemy while the gun is being loaded.

"More elevation can be given to the guns on the turret system than on the broadside, as ports are now fitted.

"So far as being able to keep the gun, when loaded, always pointed toward the object, a greater rapidity of fire is obtained by the turret system, the captain of the turret having at all times a distinct view of his object, which, in a sea-way, would be frequently lost sight of by the captain of a broadside gun; and further, the object is less liable to be interrupted by smoke.

"(*b*) There is better protection for the men fighting the gun who are actually inside the armour-plated part of the turret, and also for the gun and carriage, in the turret system than in the broadside.

"(*c*) We believe that a turret, with 6-inch armour-plating, would be almost invulnerable, as regards penetration, against any gun of less weight than 12 tons.

"(*d*) A ship armed with two turrets has the advantage of being able to direct all her guns on the same object on more bearings than by any other known plan; and of throwing a heavier weight of metal on either broadside than can be done by any armour-plated vessel of equal size and tonnage armed in any other mode now afloat, or that has yet been designed, so far as we are aware of.

"(*e*) Of two vessels of the same speed, one armed on the broadside, and the other armed with two turrets, the latter has a greater facility of placing herself to an advantage in action, by keeping head to sea in a seaway, than the broadside ship.

"(*f*) If the ship were totally dismasted and the screw disabled, a one-turret ship would probably, and a two-turret ship certainly, be able to continue the action to greater advantage than a ship armed on any other plan under like circumstances.

"(*g*) When a ship has to go through an intricate channel, or up a winding river, when the enemy is always in range, the turret system would give greater facility to a one-turret ship probably, and a two-turret ship certainly, of keeping her guns bearing on the enemy, while the ship would be following the course of the channel or stream."

Admiral Goldsborough says—"A difference of opinion also exists among naval minds, both at home and abroad, as to whether the better expedient is to use the guns of an iron-clad turretwise, or in broadside ports, under a covered plated deck. For my own part I have little doubt upon the subject, particularly if the vessel herself be confined, as in my judgment she ought to be, to moderate dimensions; to such in effect as, with a high velocity, will offer sufficient momentum, used as a ram, to crush effectually any antagonist whatever capable of sea-service; and more than this, to my apprehension, is obviously worse than superfluous. The turret I regard as decidedly preferable, and mainly for these reasons:—It renders one gun of a class equivalent to at least two of the rams disposed in opposite broadside ports, and this with a heavy reduction of crew. It admits the use of much heavier guns. It does not necessarily involve a breadth of beam antagonistic to velocity. It affords a better protection to guns and men; and withal it secures the fighting of guns longer in a sea-way."

"I have met with no ideas with regard to sea-going ironclads that have impressed me so forcibly as those of Captain Coles, of the British Navy; and I think his system in the main the best that can be adopted at present. In my humble opinion he meets the difficulties of the case better than they have yet been met in any other quarter; and he displays throughout his exposition a fertility of resource, a fund of ingenuity, common sense, and professional experience, that confers upon him distinguished credit."

The two letters which follow will show the present state of the question as it regards the Admiralty:—

Auckland Villa, Southsea, Sept. 9th, 1865.

My Lord,—Two months having elapsed since the Committee's report on the designs of a sea-going ship were sent in, a copy of which was forwarded to me, I beg leave to point out that I have received no answer to my reply of July 11th, and again to assure their Lordships of my readiness to co-operate with them in carrying out the suggestions of the Committee to build a sea-going ship with two turrets, and I have respectfully to request an answer at their Lordships' earliest convenience.

I have the honour to be, my Lord,
Your obedient servant,
Cowper P. Coles.

Vice-Admiral the Right Honourable
Lord Clarence Paget, C.B., &c.

Admiralty, 14th Sept.

Sir,—I have received and laid before my Lords Commissioners of the Admiralty your letter of the 9th instant, and I am commanded by their Lordships to acquaint you that when they received your letter of the 11th July last, they did not consider that an answer was required.

The design submitted by you for a sea-going turret-ship had been referred to a Committee, and had not been deemed by them suitable for adoption. My Lords, after considering the Committee's report, deemed that the preparation of a design for a sea-going ship with two turrets should be submitted to the Department of the Controller of the Navy. Many important points connected with this difficult problem have been raised for preliminary decision, which must be settled before the design can be satisfactorily proceeded with, and these points are now under their Lordships' consideration. The approaching trials of the *Scorpion* and *Wyvern* may assist in the elucidation of these difficulties.

Should the Controller succeed in laying before their Lordships the outlines of a design which may appear likely to produce a ship adapted to carry at sea two revolving turrets on your plan, my Lords, before proceeding to carry out the design, will communicate it to you for any observations you may have to offer, and will avail themselves of your assistance in the arrangement of the details.

I am, Sir, your obedient servant,
W. G. Romaine.

To Captain Cowper P. Coles, R.N.,
Auckland Villa, Southsea.

Captain Coles's letter is clear enough, but not so the Admiralty letter, as it is difficult, if not impossible, to make out who is to design this sea-going two-turret ship. We cannot suppose that it will be either My Lords of the Admiralty or the Controller of the Navy, they being naval men, and not naval architects nor shipbuilders.

The Chief Constructor of the Navy, from his position, is the proper authority to decide this question; but some of Mr. Reed's opponents might say of him, what we ourselves are scarcely prepared to endorse, that he has proved himself incapable of designing an ordinary ironclad.

ART. XIII.—*An Inquiry respecting the Form of least Resistance for a Ship; the Position of the Centre of Gravity with respect to the Ship's length; and the means of reducing the Motions of pitching and 'scending to a minimum.* By WILLIAM HENWOOD, Esq., Naval Architect, Member of the late School of Naval Architecture. Being a Reprint from the *United Service Journal* for 1833.

THE determination of that form for the bottom of a ship which will meet with the least resistance in moving through the water is obviously the desideratum in the science of naval architecture. That there must be a form of body for a ship which can be impelled more easily in water than any other body of equal magnitude and weight, it is scarcely possible to doubt. The great number of experiments on the resistance of fluids to the motions of solid bodies of different forms, which have been made by various scientific individuals, and by learned bodies and societies in this and in foreign countries, makes this point sufficiently certain, and shows that the form of least resistance for a ship has universally been regarded as an object of pursuit of very great importance.

The endeavours of several highly distinguished writers to apply mathematical science to the investigation of the form of least resistance for a solid body moving in water, have, it is well known, been altogether unsuccessful. Every theory of resistance hitherto propounded has been so completely built upon hypotheses unsupported by or at variance with facts, that the mathematical investigations in each and all of them must be regarded merely as exercises in that science which has been most advantageously applied in developing the principles of the motions and equilibrium of solid bodies. It has been, and perhaps it ever will be, found utterly impracticable to form an hypothesis upon which a theory of resistance of fluids can be established that shall include all the circumstances which materially affect the velocity of a solid body moving in a fluid. And, unless such an hypothesis can be discovered, it is in vain to look for a theory of resistance that may with confidence be applied in comparing the relative excellence of ships as fast sailers.

The little advantage which has been derived from the numerous attempts to ascertain the comparative resistances of water to the motions of solid bodies, by means of experiments with models of an almost innumerable variety of forms, renders it improbable that a result of practical utility would ever be obtained from a repetition of experiments made in a similar manner. *Experiments* from which it would be reasonable to anticipate results useful for the purposes of naval architecture must be made on ships, and not on bodies of insignificant dimensions and weight. The amount of expense that would be incurred by making experiments on ships at sea is, however, so great that it is very unlikely much benefit will accrue to naval science from the source just mentioned.

Whilst, therefore, it appears we are unable to avail ourselves of the assistance of mathematical calculation in the investigation of the form of least resistance for the bottom of a ship, and whilst so little advantage can be expected from experiments made either with models or with ships, we may in the meantime endeavour to arrive at a solution of the problem of least resistance for a ship, in as strict a manner as the nature of the subject admits, by the method of induction from observations and well-ascertained facts.

Let us, in the first place, endeavour to ascertain the effects which necessarily arise in consequence of the action of the water on the bottom when a ship is sailing with considerable velocity.

Suppose a ship 150 feet long to be moving at the rate of 15 feet a second, so as to pass over a space of 75 feet, or half her length, in five seconds. It is evident that, during this period, a body of water which must be represented in cubic content by the area of the midship section of the ship, multiplied by half her length, has been removed from the situation in which it was at the previous instant of time. And the important question which presents itself for our careful consideration is, whither, and in what direction, has so large a body of water been impelled and dispersed in so short a period?

It is perfectly well known that, when a ship is sailing with considerable velocity, there is an elevation of the water afore the greatest breadth, and a contemporary depression of the fluid abaft. The attempts which have been made to ascertain the height of the elevation of the water at the bows have not been successful. Chapman, the celebrated Swedish naval architect, has assumed, in his treatise on ship-building, that when a ship is sailing with a velocity of 20 feet a second, the elevation of the water forward is 6 inches, and the depression abaft 6 inches. The same writer, however, has stated that "unless the ship sails in smooth water, the elevation or depression of the fluid will be reduced to nothing, or to very little." As the sea is never remarkably smooth when a ship is sailing with a velocity of 20 feet a second, it is to be supposed Chapman would have assumed a greater height of elevation and a greater depth of depression of the fluid if he had not entertained the extraordinary notion that the elevation and depression of the water at the head and stern of a ship are much less when the sea is rough than when it is smooth. Dr. Robison has stated, in his "Mechanical Philosophy," vol. ii., p. 288, that he "has often looked into the water from the poop of a second-rate man-of-war, when she was sailing 11 miles per hour, which is a velocity of 16 feet per second nearly; and he not only observed that the back of the rudder was naked for about 2 feet below the load water-line, but that also the trough or wake made by the ship was filled up with water, which was broken and foaming to a considerable depth, and to a considerable distance from the vessel."

It has by some persons been supposed that the height of the elevation of the water at the bow of a ship might be found by observation, when a ship is at anchor in a strong tide. It has been argued that there is then a sort of prow of water formed by the running stream before the bows of a ship at anchor, which must be exactly similar to the accumulation and heaping up of the water at the fore-part of a ship when she is sailing in the open sea, with a velocity of motion corresponding with that of the tide. It also has been supposed that there must be a similar depression at the stern in the two instances.

Dr. Robison appears to sanction this notion when, in his celebrated article on the Resistance of Fluids, in the volume above referred to, he says, p. 265—"The force which is necessary for keeping a body immoveable in a stream of water flowing with a certain velocity is the same with what is required for moving the body with this velocity through stagnant water."

That there is, however, a very material difference between the force required to move a ship with a given velocity in still water, and that requisite to prevent her from being moved by a strong tide, the surface of which moves with the same velocity, is most obvious. In the one case, every point of the ship, from the keel to the water-line, passes through the water with the same velocity; and in the other case, the water at the surface flows past the ship with a greater velocity than the water below the surface, and perhaps at a much less depth than that of the keel of the vessel the water is nearly, if not perfectly, stationary. There is, therefore, so essential a dissimilarity in the two cases, that the elevation of the water, before a ship moving in still water, cannot possibly be the same with that before a vessel lying at anchor in a running stream.

That the height of the elevation of the water cannot, with any degree of certainty, be found by observation, will appear, if we consider that the direct resistance of the water against a ship would of itself tend to elevate the bow and to depress the stern; and the increase of buoyancy arising from the elevation of the fluid forward and the diminution of buoyancy arising from the depression of the water abaft must have the same tendency. And thus it must happen, that in proportion as the level of the sea round a ship in motion is changed from its natural coincidence with the horizon, in the same, or in probably a greater degree, will that section of a ship which is called the load-water section in her quiescent position in still water become inclined to the horizon. The perpendicular height of the elevation of the water at the head of a ship and the perpendicular depth of the depression at the stern are, therefore, in all probability, much greater than, from mere observation, we are apt to suppose; and, accordingly, the quantity of fluid actually elevated above the natural level forward, as well as the depression abaft, must also, it is highly probable, be much greater than it has usually been considered.

The extent of the elevation of the water round the bows of a ship moved by sails in still water must be inferred from a consideration of the cause by which the heaping up of the water is produced. A ship when moving, as above supposed, at the rate of 15 feet a second, displaces, every five seconds, a body of water, the capacity of which may be represented by the area of the midship section multiplied by half the length of the ship, which product, in a frigate 150 feet long, is about five-sevenths of the whole displacement. The water thus displaced by a ship as she is moved ahead is always from the instant of the first impulse it receives from the motion of the ship impelled by the ship nearly in the direction of her course; or in directions rather diverging from that course of the ship, more or less, according to the degree of sharpness of the bows. The water so impelled by the ship, in a direction in some degree diverging from the line of her course, on either side of the ship, must, of necessity, escape in that direction in which it will meet with the least resistance. It is perfectly certain it cannot escape by moving downwards; because the opposition to its motion would be greater than in the upward direction; and it cannot escape in the horizontal direction for the same reason; and it must therefore escape by being, in the first place, elevated above the natural level of the surface. It is thus, as I conceive, that a body of water, equal in the case of a frigate 150 feet long to five-sevenths of the whole displacement, must be impelled forward and elevated above the natural level of the surface during each succeeding interval of time in which the ship moves through the distance of half her length. The effect of the force of gravitation, or hydrostatical pressure, acting on the water driven ahead of the ship, and forced to rise above its natural level, must, of course, disperse the fluid as it rises, and occasion the heaped-up water to be diffused to a considerable distance all round the bows. The extent of the elevated surface of the water, and the height at which it is maintained above the common level of the sea, must be greater or less, according as the velocity of the ship is more or less rapid.

From the well-known fact of the great length of a ship's wake when the velocity of sailing is considerable, it may, I consider, be fairly concluded that the elevation of the water round the fore-part of a ship must necessarily extend to as great a distance as the observations just made would appear to indicate. The time of a ship's sailing through the length of her wake is, of course, equal to that during which the level of the surface is disturbed; and nearly the half of this period is probably the time in which the elevation and dispersion of the fluid round the bow is effected, and the remainder that of the return or flowing back of the water towards the ship's wake.

The depression of the water at the stern of a ship sailing with considerable velocity has been mentioned as a fact of equally frequent observation with the elevation of the water at the bows. The void space at the stern, formed below the natural level of the surface, is, it is obvious, equal in extent to the body of water elevated above the true level of the surface round the fore-part. It has by some writers been supposed that the water afore the greatest breadth is transmitted round the sides towards the stern; and that it is by such flowing of the water round the sides from the fore to the after part of a ship that the void space abaft is filled up. That this notion is founded upon a very imperfect view of the circumstances connected with the motion of a ship in the water, the foregoing observations I think sufficiently manifest. A little reflection will oblige us to conclude that when a ship is in motion, every particle of the fluid contiguous to the after-part will, at the instant after it has been left by the ship, be impelled by the pressure of the particles behind it into the void space formed at the stern, in a direction nearly horizontal and at right angles to the curvature of the adjacent water-line of the ship; and that consequently the entire void space at the stern of a ship in motion must always be filled up by the water rushing in from abaft, and not by water flowing from forward round the sides of the ship towards the stern. The water contiguous to the after-part is thus, as I conceive, made constantly to follow the ship as she is moved ahead, and fill up the void space at the stern.

The observations which have been made elucidate the question above proposed,—whither and in what directions is the large body of water displaced by a ship 150 feet long, moving at the rate of 15 feet a second, during each succeeding interval of time in which she is moved the distance of half her length, impelled and dispersed?

And they appear to show that as a body of water equal to about five-sevenths of the displacement must be elevated above the natural level of the surface every five seconds by the ship when moving at the rate supposed;—if the ship were to be suddenly stopped, and five seconds were the time in which the water elevated round the bow would flow back towards the stern, by its hydrostatical pressure, so as to restore the surface to its true level;—then it is plain that a quantity of water equal to about five-sevenths of the displacement must be continually maintained at an elevation above the natural level of the surface whilst so rapid a motion of the ship continues. That the surface of the water would be restored to its accustomed level, in the circumstance supposed, in a shorter period of time than five seconds it is impossible to believe, as there must of necessity be a transfer of the elevated quantity of water through the space of at least the length of the ship; and evidently if this transfer were effected by the flowing back of the fluid produced by its hydrostatic pressure, with as great a rapidity as the ship was moved forward, ten seconds would be occupied in the restoration of the level. It is not, however, my object to obtain an accurate conclusion on this point, where, of course, accuracy cannot certainly be obtained; I wish simply to avoid an erroneous conclusion. I shall, therefore, henceforth consider that a body of water equal to about five-sevenths of the displacement is maintained in an elevated position round the bow of a ship when she is moving uniformly at the rate of 15 feet a second,—that, of course, the greater the velocity or resistance of the ship, the greater will be the elevation and the depression of the water; that a certain degree of velocity for the same ship is always accompanied with a corresponding degree of the elevation and depression of the water, and that the greater the difficulty of producing that degree of elevation and depression of the water which is necessarily occasioned with its concomitant velocity, the greater must be the resistance of the ship.

The question on which it is intended to bring this conclusion to bear is whether, of two ships, of the same displacement but of different forms, one having great fulness of bottom near the water-line and the other great fulness near the floor, all other things being the same, or as nearly as possible the same in both, the one will not meet with less resistance than the other? But before we apply what has been advanced to this interesting and highly important question, it is proper to enter into a consideration of the arguments adduced on either side of the controversy—whether the resistance of water to the motion of solid bodies is or is not greater at greater depths?

It is stated by Dr. Robison, in his "Mechanical Philosophy," vol. ii., p. 293 (and in the "Encyclopædia Britannica," art. *Resistance*), "This point, or the effect of deep immersion, is still much contested; and it is a received opinion by many not accustomed to mathematical researches, that the resistance is greater at greater depths. This is assumed as an important principle by Mr. Gordon, author of 'A Theory of Naval Architecture,' but on very vague and slight grounds; and the author seems unacquainted with the manner of reasoning on such subjects."

On page 364 of the same volume, however, there appears something very like an admission by Dr. Robison of the truth of the principle he has, in the above-quoted passage, so confidently impugned. Of Mr. Gordon's book I may just mention, I have not had an opportunity of perusing it.

In "supposing a sphere moving near the surface of the water, and another moving equally fast at four times the depth," Dr. Robison says, "If the motion be so swift that a void is formed in both cases, there is no doubt but that the sphere which moves at the greatest depth is most resisted by the pressure of the water. If there is no void in either case, then, because the quadruple depth would cause the water to flow in with only a double velocity, it would seem that the resistance would be greater; and, indeed, the water flowing in laterally with a double velocity produces a quadruple non-pressure. But, on the other hand, the pressure at a small depth may be insufficient for preventing a void, while that below effectually prevents it; and this was observed in some experiments of Chevalier de Borda. The effect, therefore, of greater immersion or greater compression in an elastic fluid (as water) does not follow a precise ratio of the pressure, but depends partly on absolute quantities. It cannot, therefore, be stated by any very simple formula, what increase or diminution of resistance will result from a greater depth." . . . "It is only in great velocities where the depth has any material influence."

That, when two equal spheres are moving in water with the same velocity, one a little below the surface, suppose one foot, and the other at four times the depth, or four feet, there would be a void formed behind the one as certainly there would behind the other, it is impossible to doubt;—whatever may have been observed in some experiments of Chevalier de Borda;—because, however rapidly the water follows or closes in on the posterior sides of the spheres, and however much more rapidly the water may follow or close in behind the deeper sphere than behind the other, still an interval of time must elapse between each indefinitely small movement of the spheres and each consecutive indefinitely small movement of the fluid.

That a diminution of resistance should result from a greater depth is assuredly out of the question. But that an increase of resistance does result from a greater depth in great velocities, is evidently supposed by Dr. Robison. And this is an admission directly at variance with the opinion so tenaciously adhered to by this writer, in the former part of his justly celebrated article on Resistances, and which indeed has been, as Dr. Robison intimates, the prevailing notion entertained on the subject.

In order, however, the more fully to investigate the truth or the fallacy of the principle in question, let us examine the distinct assertion of Dr. Robison, on p. 342 of the same volume, that "a plane of two feet wide and one foot deep, when it is not completely immersed, will be more resisted than a plane two feet deep and one foot wide; for there will be an accumulation against both; and even if these were equal in height, the additional surface will be greatest in the widest body; and the elevation will be greater, because the lateral escape is more difficult."

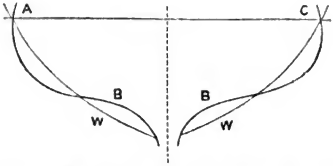
For this reason why the resistance on the broad plane with two feet area under the water would be greater than that on the deep plane with an equal part of its area immersed, it has been taken for granted, that when both planes are moved with the same velocity, the lateral escape of the water will be more difficult in the case of the broad plane than in that of the deep plane. Now, the lateral escape of the water is caused by the accumulation before the planes and the contemporary depression of the surface behind them. The height of the elevation depends almost entirely on the quantity of fluid displaced and driven ahead; and obviously an equal quantity will be displaced and driven ahead by planes of equal area whether broad or deep, when they move with equal velocity. The principal dissimilarity in the circumstances of the motions of these two planes, however, appears to be that the water displaced and impelled forward by the motion of the deep plane must necessarily be raised up from twice as great a depth in opposition to a greater hydrostatical pressure as that displaced by the motion of the broad plane, before it can find a way of escape. A very small portion only of the displaced fluid, in consequence of the lateral pressure of the fluid, can escape round the edges or borders of the planes; the principal part of it must first be elevated above the level of the surface, and then flow away in all directions, by the force of the hydrostatical pressure produced by the head of water accumulated before the planes.

The quantity which may escape over the edges of the planes must be forced to move past the borders of the planes by the influence of the hydrostatical pressure of the elevated water; and certainly but a small portion of the displaced fluid could escape in this way. It does seem, in the case of the deep plane, as the greater part of the displaced fluid must be raised from a double depth, and raised thence in opposition to a greater perpendicular pressure of the fluid, and must necessarily have a longer and certainly a more difficult way of escape before it can arrive at the trough or wake formed on the posterior side of the plane,—that the resistance of the water, so far as it arises from the effort to displace and disperse the fluid in this way, must be greater on the deep plane than on the broad one. And with respect to that part—certainly a small part—of the displaced fluid which escapes by passing round the edges or borders of the planes, it is worth while to observe that the circumstance of the water being elevated before the planes must cause some of the fluid to escape underneath the planes; and it would undoubtedly escape more easily under the broad plane than under the deep one, as may be shown thus:—Suppose the elevation before each plane to be one inch, and the depression behind also one inch, the escape of the water under the broad plane may be considered as being caused by the pressure of 13 inches depth of water acting in opposition to that of 11 inches; and the escape of the water under the deep plane will be produced by the pressure of 25 inches depth of water acting against 23 inches. This result would be similar, whatever may be the height of the elevation of the fluid. And the escape round the vertical edges of the broad plane would be, in a similar degree, more easily effected by the fluid than round the vertical edges of the deep plane. The difference in the facility of escape of the particles of fluid arising from the inequality of the lengths of the immersed borders of the two planes cannot, I think, be satisfactorily estimated. The comparative force of resistance on the two planes must depend principally on the difficulty of displacing and causing to escape the water necessarily elevated above the level of the surface; and the resistance from this cause must, as we have seen, be greater on the deep plane than on the broad one. The conclusion, therefore, to which this train of reasoning appears to lead us is, that, on the whole, the resistance on the deep plane must certainly be greater than on the broad plane.

Again, if we consider the effect of the water on the plane from the commencement of the motion,—as we know the pressure of the fluid is greatest against the deepest surface when both are at rest,—the pressure of the fluid must of necessity be likewise greater during the first indefinitely small portion of the space moved through by the planes; and no reason can be assigned why the pressure should not also continue greater during the second and third, and every succeeding division of the path described; and we cannot, therefore, but conclude that so far as the resistance on the planes is identical with or dependent on the pressure against them, the resistance on the deep plane is greater than on the broad one.

How far Dr. Robison has considered the resistance of fluids to be identical with or dependent on the pressure against the resisted bodies, we may gather from what he has most unequivocally stated in the same valuable article. On p. 269 he says, "The fundamental principle of the resistance of fluids—namely, that the resistances on similar bodies are as the surfaces, the density of the fluid, and the square of the velocity jointly—when taken in its proper meaning is, that the impulse or resistance of fluids is a pressure opposed and measured by another pressure, such as a pound weight, the force of a spring, the pressure of the atmosphere, and the like." Again on p. 272 he says, "Absolute impulse means the actual pressure on the impelled surface arising from the action of the fluid, whether striking the fluid perpendicularly or obliquely." And this "pressure is always perpendicular to the surface." And on p. 273 Dr. Robison explains that "relative or effective impulse means the pressure on the surface, estimated in some particular direction."

According to this view of the subject,—which, it appears to me, is perfectly just,—the resistance of water to the motion of a solid body is neither more nor less than the pressure of the fluid against the moving body; and if this is the fact, we see the justness of Dr. Robison's assertion respecting the resistance on the two spheres, one moving at four times the depth of the other, that "no doubt that the sphere which moves at the greatest depth is most resisted;" although Dr. Robison has offered no reason for the truth of this assertion. If we admit that a motion of the spheres cannot take place without causing a certain degree of elevation of the surface above and before them, then there can be no doubt that as the pressure is greatest against the deepest sphere when both are at rest, and as no reason can be assigned why it should not also continue greater after the commencement of the motion, and as the deepest sphere must with the greatest difficulty produce the necessary motion and elevation of the water in its path, it must meet with the greatest resistance. In these two cases, therefore, of the planes and globes, it is presumed it has been shown we have sufficient reason to conclude the resistance is greater at greater depths.



Let A B C, A W C, be two vessels of equal length and breadth at the load water-line, having their midship sections A B C, A W C, equal in area, but unlike in form; the sides of the vessel A B C being upright being between wind and water, and the sides of A W C falling inward below the water, as the figure represents; and let the vessels be the same, or as nearly as possible the same, in all other respects.

It is evident that the centre of gravity of the section A W C will be lower down than that of A B C, and as all the vertical-transverse sections of each vessel will partake of the characteristic form of the midship section of each respectively; and as the corresponding vertical transverse sections of each vessel will be equal, or very nearly so, in area, as they must be, in order that the same displacement may be obtained with the same length;—it follows that the centre of gravity of each vertical-transverse section of the vessel A W C will be farther below the water's surface than the centre of gravity of each corresponding vertical-transverse section of the vessel A B C, and consequently the centre of gravity of displacement of the wedge-form vessel A W C will be at a greater depth below the surface of the water than that of the vessel A B C. In conformity with the foregoing reasoning, the resistance of water on the area of the midship section A W C of the wedge-form vessel must be greater than that on the midship section A B C; because the areas are equal, and the centre of gravity of the former is lower than that of the latter. And if the resistance of a ship depends on the form of the midship section more than on the form of the fore and after bodies, as it has been concluded by some eminent individuals that it does:—it appears to result, that the whole resistance on the wedge-form vessel A W C must be greater than that on the other vessel A B C.

From what was advanced in the former part of this paper, it was concluded that a certain degree of velocity for a ship is always accompanied with a correspondent degree of elevation and depression of the water; and that the greater the difficulty of producing that degree of elevation and depression of the water which is necessarily produced with its conjoined velocity, the greater must be the resistance of the ship.

Now it is obvious that the water displaced and elevated by the wedge-form vessel A W C must be forced upward from a greater depth in opposition to a greater hydrostatical pressure than that raised up by the vessel A B C; and as the same quantity is displaced by each vessel, and an equal quantity must be elevated by each when they move with the same velocity, it also appears from this mode of considering the question, that the resistance on the wedge-form vessel A W C must be greater than the resistance on the vessel whose distinguishing form is described by A B C.

The remarkable experiments made by M. Romme, an account of which I quote from "Papers on Naval Architecture," vol. i., p. 257, furnish us with as strong presumptive evidence as it is perhaps reasonable to expect will ever be derived from experiments on models, that the resistance of water to the motions of ships does in a very material degree depend on the form and magnitude of the area of their midship sections; and the result of these experiments confirms, to a certain extent, the validity of the conclusion to which we have arrived. One of the bodies on which the experiments referred to were made was "an exact model, *L'Illustre*, a French seventy-four, on a scale of an inch to a foot, making the length of the model about 14 feet, and its breadth 3 feet 8 inches; the other model had the same midship section, the same length stem and stern-post, with the fore and after parts formed by straight lines drawn from the midship section to the stem and stern-post."

The Commissioners MM. le Chevalier de Borda, de Bory, and l'Abbé Bossuet, who examined the account of the experiments of M. Romme, and made a report on them to the French Academy, speaking on these two models, gave the following account of the experiments made on them:—" M. Romme a comparé les résistances de ces deux modèles, à différents tirants, d'eau. Il faisoit ces expériences dans un canal de 40 pieds de largeur et de 7 à 8 pieds de profondeur. De chaque coté du canal on avoit placé deux piquets á 75 pieds l'un de l'autre, dont le premier étoit à 60 pieds du point de départ, afin que les corps eussent le temps de parvenir à une vitesse uniforme avant l'observation. Ces piquets étoient garnis de pinnules au moyen desquelles on observoit l'instant ou les corps passoient par les travers de ces piquets. Une compteur á secondes servoit à déterminer le temps qu'ils employoient à parcourir les 75 pieds. Enfin, chaque expériences étoit répétée plusieurs fois, et on prenait un résultat moyen pour obtenir plus de précision. Le résultat de ces premières expériences a été que les deux modéles à tirant d'eau égal, et mus par les mêmes poids, out toujours éprouvé la même résistance. M. R. a encore trouvé qu'en tirant successivement, d'abard par l'étrave et ensuite par l'étambot, celui des deux modèles dont la surface étoit formée par les lignes droites, la résistance étoit la même. Enfin ayant coupé les deux modèles en deux parties égalls, et ayant joint l'avant du premier, avec l'arrière du second, et l'avant du second avec l'arrière du premier, les deux corps ont toujours parcouru leur espace de 75 pieds dans le même nombre de secondes, soit le mouvement se fit par l'étrave ou par l'étambot."

They proceed to mention three objections to the results of these experiments. The first is, the shortness of the time the models were in motion, being with the smallest velocity only 27″, and with the greatest velocities only 15″, 14″, and even 13″. The second objection is, that from the great difference of form of these two bodies, the one being probably too sharp, and the other too full, the resistance they experienced might vary equally from that of some intermediate form. The last objection they mention, which they consider the most important, is the apparent disagreement between the results of these experiments and the effect produced on ships at sea in their velocity, by increasing or diminishing the difference of their draught of water forward and abaft. In examining these objections, they show what may be advanced on the other side of the question in favour of M. Romme's experiments, and on the last objection make the following very excellent remarks:—"That not any one of the theories of the resistance of fluids explains this effect, and that by calculating according to any one of them the change which would be produced by a small variation in the difference of draught of water forward and abaft, the alteration would be extremely small, so as not in any tolerable degree to account for the fact, which they, therefore, consider may not arise from the difference of draught of water influencing the resistance; but that, probably, from the inclination of the masts being altered, by which the sails take a different position in relation to the wind, they may be set more or less advantageously; or that the sails forward and aft being better balanced, and forming an equilibrium with the resultant of the force of the water on the bottom, there may be no necessity for keeping the ship in its direction by means of the rudder, which always retards the sailing."

They finish their report by observing—"Nous concluons de l'examen que nous venons de faire des expériences de M. R., que s'il n'est pas exactement vrai que la forme des proues des vaisseaux n'influe pas beaucoup sur la résistance qu'ils éprouvent, par le choc de l'eau, du moins il est très-probable que les proues peuvent beaucoup varier, le maître couple restant toujours le même, sans que la résistance éprouve des changemens sensibles."

With respect to the above objections I observe, that not only the shortness of the time the models were in motion, but also the slowness of that motion in comparison with the greatest velocities of ships,—although a more rapid movement could not perhaps easily be obtained in making such experiments,—and the small size, in comparison with the bodies of ships, of these nevertheless large models, render the results of such experiments of very uncertain utility as a basis for a conclusion respecting the best form of body for a ship.

Concerning the second objection I remark, that a medium form between that of the model of *L'Illustre* and the extremely sharp form of the other model would be by no means suitable for a ship, even if the resistance on it were something less than on either of the two models. But if that view we have just now exhibited of the resistance of water to the motion of solid bodies is correct—viz., that the resistance is neither more nor less than the pressure of the fluid against the moving body, and that it depends on the quantity of water which must be elevated before the body, and on the difficulty of heaping up the elevated fluid—it is by no means probable that a medium form between the two tried by Romme would be less resisted than either of his two models. It is to be supposed, that as these experiments were repeated many times, and a mean result taken for the sake of greater precision, and as they were subjected to the scrutiny of persons so competent to examine them, that if there had been any defect in the apparatus employed to produce motion, or any other circumstance calculated to lead to an erroneous conclusion, it would have been discovered, if not by Romme himself, certainly by one of the three distinguished Commissioners. The result appears to show undeniably, as far as experiments with models can show anything, that the resistance of a ship depends principally on the form and area of the midship section.

The third objection mentioned, and which the Commissioners are stated to have considered the most important, remains to be noticed. It is obvious that either an increase or a diminution of the difference in the draught of water of a ship forward and abaft is always produced by a removal of weight in a longitudinal direction. The consequence of altering the longitudinal positions of the weights in a ship at sea is, that her pitching and 'scending motions are either increased or diminished; and as the effect of any weight in enlarging the angles of the pitching motion is in proportion to the weight multiplied by the square of the distance of its centre of gravity from the transverse axis of the ship, a very great difference may evidently be, and doubtless frequently is, produced in the pitching motion of a vessel, by the same transfer of weight which occasions but a small alteration of the difference of draught of water at the head and the stern. This very important consideration does not appear to have been attended to by the examiners of Romme's experiments, who seem rather to have supposed the change of the position of the centre of effort of the sails consequent on the alteration of the difference between the draughts of water of a ship forward and abaft, to the cause of the effects observed in ships at sea in the circumstance referred to. Neither of these objections, however, affect the conclusion derived from the experiments of M. Romme, which, as expressed in the report of the Commissioners, is that "at least it is very probable the form of a ship may be varied considerably, the midship section always remaining the same without the resistance of the water being sensibly altered."

The discrepancy between the results of the experiments of Romme, and the results of experiments made by others on the resistance of bodies moving in water, is perhaps to be attributed to the diminutive size of the bodies used in all other experiments, and to the forms being so unlike that of a ship, in comparison with the models of Romme.

As it has been shown we have sufficient reason to believe the resistance of water on a plane of a given area is greater in proportion as the depth of its centre gravity is greater; the resistance on the midship section of the wedge-form vessel A W C must be greater than that on the section A B C; and so far as the resistance of a ship depends on the form and area of her midship section, the resistance on the wedge-form vessel must be greater than that on the vessel with upright sides and a flat floor. The result of Romme's experiments accordingly confirms, to a certain extent, the conclusion above stated respecting the comparative resistance of the water on the two supposed forms of a ship. It is concluded, therefore, from all which has been advanced, that the resistance of the water to the motion of a ship is a minimum when, *cæteris paribus*, the centre of gravity of displacement is at the least practicable depth below the line of floatation.

We may now advert to a very highly important consideration in the construction of a ship, which is—how far before or abaft the middle point of her length the centre of gravity of a ship, or that of the displacement (which are in the same vertical line) should be situated. Chapman has stated that this point is usually placed between one-fiftieth and one-hundredth of the length of a ship before the middle. Experience alone appears to have prescribed these limits for the position of the point in question; and no inquiry whatever, so far as I am aware, has hitherto been instituted for the purpose of ascertaining whether this point should be placed more nearly to one of these extremes than to the other, or even beyond either of them. The easiness and the extent of these motions of a ship are, of course, affected also very materially by the longitudinal positions of the weights. It has already been intimated that the effect of every weight belonging to a ship in increasing the angles of the pitching motion is in proportion to its gravity multiplied by the square of its distance from the transverse axis which passes horizontally through the ship's centre of gravity. In other words, the effect of every weight is in proportion to its "moment of inertia."

The velocity of sailing of a ship, it is sufficiently well known, depends greatly on the extent and easiness of the motions of pitching and 'scending. Ships which pitch heavily and deep in a sea must of necessity sail slowly; and this has uniformly, I believe, been found to be the case, and such ships are always to be regarded as badly-formed structures. It will, I think, be admitted by every one that the smaller the angles of pitching and 'scending are, the faster *cæteris paribus* will a ship be made to move through the water by the action of the wind on the sails; and these angles will, of course, be a minimum when the causes which produce them are also the least possible. The forces which produce these motions are the combined action of the water on the bottom and the moments of inertia of all the weights of the ship.

The sum of the moments of inertia of all the weights of a ship will be a minimum (provided the weights are concentrated as much as possible) when the sum of the moments of inertia of all the weights on one side of the vertical plane through the transverse axis of the ship is equal to the sum of the moments of inertia of all the weights on the other side of the same plane. And the angles of pitching and 'scending, therefore, so far as they depend on the effect of all the weights when the ship revolves about her transverse axis, will be a minimum when the sum of the moments of inertia afore the above-mentioned plane is equal to the sum of those abaft the same plane.

The angles of pitching and 'scending, so far as they depend on the effect of the action of the water on the bottom, will be a minimum, when the moment of inertia of that part of the displaced volume which is abaft the vertical plane through the transverse axis of the ship is equal to the moment of inertia of that part which is afore the same plane.

The pitching and 'scending motions of a ship are, therefore, the least possible when the sum of the moments of inertia of the weights on each side of the vertical plane through the transverse axis of the ship are equal; at the same time that the moments of inertia of the fore and the after bodies of the ship are also equal to each other; or the pitching and 'scending of a ship will be a minimum when the angles of pitching are equal to the angles of 'scending.

Ships of war in general have been so constructed that their angles of pitching have been considerably greater than the angles of 'scending. On board the *Wolf* and the *Tyne*, two of the ships of the experimental squadron of 1827, it was found, by no means of a suitable instrument, that the angles of pitching were generally about twice as great as those of 'scending. ("Papers on Naval Architecture." Vol. II. p. 299.)

In order to construct a vessel in which the pitching and 'scending shall be as little and as easy as possible, it is evident from the observations which have been made, that the distance of the centre of gravity of the fore body afore the vertical line through the centre of gravity of the vessel, must be made equal to the distance of the centre of gravity of the after body abaft the same line; and at the same time the sum of the moments of inertia of all the weights on the fore side of the vertical plane through the transverse axis of the ship must be made equal to the sum of the moments of inertia of all the weights abaft the same plane. And, as a ship thus constructed and prepared for sea would pitch and 'scend in the least possible degree, and with the utmost easiness of motion, her velocity of sailing, so far as it is affected by these unavoidable motions of a ship at sea, would unquestionably be a maximum. Also if the centre of gravity of the whole displacement of such a ship were at the same time placed as near as it can be to the surface of the water, there is the strongest reason to believe that the direct resistance of the ship, under all circumstances, would certainly be the least possible. The lateral resistance by which a ship is prevented from falling to leeward may, of course, always be sufficiently increased by depth of keel, or false keel.

The proper distance of the centre of gravity of a ship afore or abaft the middle of her length will be determined by the expediency of reducing the sum of the moments of inertia of the weights on each side of the vertical plane through the transverse axis of the ship, to the lowest degree compatible with the preservation of an equality between the forces which act to increase the pitching and 'scending motions on each side of the same plane.

The longitudinal position of the centre of gravity of displacement of a ship has never, I believe, been determined in this manner. Naval architects have hitherto been content to place this important point somewhere between the limits generally observed. The best position of the point in question may, it is presumed, be definitively ascertained by the mode of proceeding which has now been pointed out.

I may now observe that it appears from the whole of the above investigation, that the form of body for the bottom of a ship which is the best calculated for fast sailing is that in which the centre of gravity of the displacement is at the least depth the necessary space for stowage will admit below the surface of the water, in which the same point is also so situated that the moment of inertia of all the weights may be reduced to the lowest practicable limit,—in which the centres of gravity of the fore and after bodies are at equal distances from the vertical through the centre of gravity of the ship,—and in which the sum of the moments of inertia of all the weights on one side of the vertical plane through the transverse axis of the ship is equal to the sum of the moments of inertia of all the weights on the other side of the same plane.

ART. XIV.—*Patent for raising Screw Propellers in the Royal and Merchant Navy, when Ships are not built with a screw-well.* By CAPTAIN HALL, C.B., R.N., Superintendent H.M. Dockyard, Sheerness.

As every year develops some new invention for the furtherance of the mercantile marine, so every year opens up new ideas for its ultimate perfection. At the early stage of screw propulsion both in the navy and mercantile marine, one of the great barriers which presented itself to the introduction of the screw as a propeller was, the submerging and placing of it beyond the reach and sight of the engineer. Gradually all barriers were removed and the screw was adapted to lift and lower through what is termed the screw well, by the mechanical appliance of a hoisting frame and cheese coupling in the end of the screw and screw shaft. Thus when the screw was raised, it was only necessary to place it in a perpendicular position, attach a purchase to the banjo or hoisting frame, and the screw was then raised to the deck. After a time it was found that the screw well weakened the ship, causing the stern to drop, thus casting excessive strain on the screw shaft from its being thrown out of line. Screw wells were then abandoned at the expense of not being able to get up the screw without docking the ships—a most serious consideration, as many ships have had their screws disabled, and performed the remainder of the voyage with a distorted and broken screw, impeding the speed of the ships, and materially affecting the steering. In the *Mechanics' Magazine*, November 18th, 1864, and following week, will be found a description and method of raising screw propellers when there is no screw well. It is accomplished by having the cheese coupling on the screw so arranged that it will come up horizontally instead of perpendicularly, with a banjo frame made of round bars instead of cast in one frame. The method of raising the screw is as follows:—The top part of the banjo frame is fitted with a shackle, and moveable like to a crossbar. The sheer legs are erected and the purchase attached to the crossbar. The screw is then hoisted close up under the counter of the ship, which brings the twisted edges of the screw blade above the water-line. A shackle is then attached to the twisted edges of the blade above the water-line, with two ordinary davits placed over the quarter, to which blocks and tackle are attached and hooked on to the shackles; the banjo bolts are then withdrawn, and the screw remains suspended in the tackles. Next lower one of the tackles, and the screw passes out of the aperture perpendicularly suspended to one of the davits. The davits are now removed to the other side, and the tackle hooked on to the lower edge of the blade and hoisted up level with the bulwarks just like a quarter boat, while if both tackles are lowered the screw may be landed on deck. The expense is very little to fit the gear, and the operation is one for an ordinary sailor, while a spare blade in the ship's hold might be shipped as the vessel was taking out or putting in her cargo, in any part of the world where there was no dock accommodation. At the present moment, should any of the fine ships of our mercantile navy fitted with steam power lose a blade of the propeller or foul it on their way to Australia, their voyage would be much retarded, and on their arrival at their destination docking would be necessary before they could be made efficient. Then at some considerable expense and delay, loss of saving in freight, and (taking not an unlikely view of the case) the dock might be occupied. The *Borussia*, one of the Hamburg and New York packets, broke a screw-blade when off the Start Point on her way from Southampton to New York, and had to put back to Southampton to be docked to repair the disabling damage. Had she been fitted with the proposed arrangement, she could have gone into Plymouth Sound or Dartmouth, and made good her defects in four hours, and certainly within twenty-four hours sailed, having shipped her spare blade or whole propeller, had she carried a spare one; but she returned to Southampton, was docked and detained five days in port, spending two more days going and returning from where she had met with the mishap. Channel navigation, pilotage, harbour dues, and feeding three hundred passengers, was the expense of the accident. The plan is very simple and practical, and when known will be adopted generally in vessels making long voyages, and subject to all the casualties attendant upon a submerged propeller.

Art. XV.—*Rigg's Patent Duplex Screw Propeller.* By Mr. Rumble, Inspector of Machinery Afloat, R.N.

It is generally assumed that the ordinary screw propeller acts in water as in a solid body; but such a view of its operation ignores the difference between the resistance offered by a solid and a liquid. In the former there can be no motion communicated except to the screw; but in the latter there is a very considerable movement of the water backwards, in exactly equal proportion and amount to the pressure exerted by the end of the screw shaft forwards.

From the movement of the blades of the screw, being at right angles to the vessel's keel, a little consideration will show that their revolution imparts to the water a rotary movement; and with a high velocity of the screw, the rotation sometimes absorbs the whole power of the engines, and always consumes a certain proportion of their power. This action may be distinctly seen when the screw is only partially immersed. The same principle applies to paddles, which are nothing but screws working sideways, and trusting for their propelling power to the same element as the screw propeller.

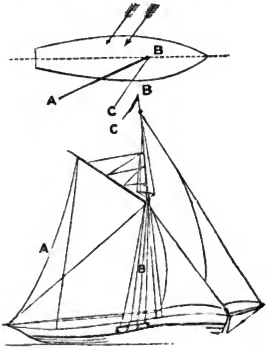
The angle or inclination at which the water is driven from the blades of the screw is found by experiment to vary very remarkably, in some cases reaching 80° or 90° from the line of the screw shaft or vessel's keel; and of course in such cases the power is nearly lost. It rarely happens, however, that the angle exceeds 30° to 60° in practice.

By the essential nature of the action of the screw, and the numberless experiments which have been made to determine its correct form, little room is left for improvement, so improvement must be sought elsewhere. But by observing the source of loss just described, we are led to consider its causes and remedy.

Having made a model in August, 1863, which gave valuable information, the Chester Canal Company kindly permitted experiments on one of their steam-tugs. It was found that the dead pull in towing is 500lb.; and an apparatus now to be described gave an additional tension of 250lb., with the same expenditure of engine power; that is to say, yielded a pure gain of 50 per cent.

Seeing that nothing done to the screw could prevent the water leaving it as if it were a twisted column, it was necessary to accept this as unalterable, so deflecting blades were put behind the screw, which acting like a nut receiving the water, untwisted it by impinging on the blades of the deflector, so that on leaving the vessel the water would resemble a fluted column, if seen or exhibited solid.

In order readily to follow the course of reasoning adopted in bringing out and perfecting this plan, the best and simplest illustration may be taken from a yacht sailing within two or three points of the wind.

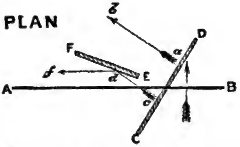


Let the arrows and streamer B C show the direction of the wind.

A B is the sail set in such a manner as to receive the wind and exert a force behind it.

It is well known how the force so gained carries the vessel on its course.

Bearing this illustration in view and for the sake of simplicity considering only one small stream of water, we can afterwards apply our results to the whole area of the screw.



Let A B represent the line of screw shaft. C D one blade of the screw, moving in the direction of the arrow *a b*. One stream of water leaving the screw at (say) 45° to the line A B; E F a deflector, or vane, placed behind the screw at (say) 22½° to the line A B; *c d f* a stream of water impinging on the plate E F.

The stream of water (*a b*) leaving the screw at 45° expends half its force in propelling the vessel, and the other half its force in displacing the water. This latter half is a total loss of power. The stream (*c d*) leaves the screw in a similar manner, but is arrested in its course by the deflector E F, and changes its direction to *d f*. Thus none of the power is employed to unnecessarily disturb the water, and bearing in mind the illustration of the yacht, it will be seen that all the power is converted into useful effect, except the inevitable loss by friction. In practice it is also found that this system much improves the steering qualities and does away with vibration.

By applying the illustration of a single stream to the whole area of the column thrown backwards by the screw, it will be evident that a very serious loss of power has hitherto lain long neglected.

With a view of ascertaining the angle at which the water is driven off from the blades of the screw (assumed at 45° for convenience of illustration), an experimental screw was constructed by Mr. Griffiths, 22 inches diameter, with four blades and a pitch of 3 feet. It was placed in a large trough and driven at 150 revolutions per minute; and the angle accurately measured at the radius given.

EXPERIMENTS TO TEST THE INCLINATIONS OF STREAMS OF WATER LEAVING THE SCREW. 10TH APRIL, 1865.

Radius.	Inclination.	Remarks.
11½ ins.	90°	
10½	80	The centre of the screw was 14½ inches below the water surface.
9½	70	
8½	55	
7½	40	
6½	30	
5½	30	
4½	30	

It will thus be seen that there is great irregularity in the inclination of the water thrown off from the screw; and it increases rapidly with a higher circumferential velocity.

Evidently, therefore, with the screw alone there is a limit to its speed and to its propelling force; but with the fixed deflector behind it, there is no such limit, because no extent of driving can waste power not afterwards recovered. The duplex screw propeller not only increases the steadiness of the vessel, with several other collateral advantages, but it greatly reduces the weight of apparatus by the essential gain of any reasonable propelling power, with increased velocity and smaller diameter of screw. These alone are sufficiently promising gains, to say nothing of the great saving in power which this apparatus was originally designed to effect. Appended is a Table of experiments carefully conducted by Mr. Griffiths (the well-known screw patentee) and Mr. Rigg, the inventor of the duplex screw, and myself, on a steam-launch belonging to Messrs. Rennie, engineers, Blackfriars Bridge; and it is confidently expected from such favourable results that a larger vessel will be placed at our disposal by the Government, to enable the principle to be still further tested, and its true practical merits ascertained.

EXPERIMENTS conducted in RENNIE'S LAUNCH, fitted with GRIFFITHS' SCREW and RIGG'S PATENT DUPLEX PROPELLER.

Date and No. of Trial.	Height of Steam.	No. of Runs.	Revolutions of Engines per Minute.	Time.	Assumed Speed in Knots.	First Mean Speed.	Second Mean Speed.	Corrected Speed in Knots.	Propeller. Speed in Knots per Hour.	Propeller. Slip. In Knots per Hour.	Propeller. Slip. Per cent.	REMARKS.
1st.	lb 45	1	164	14′ 50″	4·044	6·734	6·825					Griffiths' screw, 4 blades. Pitch 3 ft.; diameter 23½ in. Vanes 23½ in. diam.; 8 in number, set at an angle of 30 deg.
		2	175	6 22	9·424	6·917	6·886					
		3	156	13 36	4·411	6·856	6·824					
		4	165	6 27	9·302	6·793	6·729					
		5	152	14 00	4·285	6·665	4)27·264					
		6	165	6 38	9·045							
		Mean	162·83			True mean speed	6·816	4·544	4·820	·276	Positive 5·72	
2nd.	45	1	215	8 13	7·302	6·433	6·725					Screw set at 2 ft. pitch, with the vanes.
		2	208	10 47	5·564	7·017	7·032					
		3	248	7 5	8·470	7·047	6·975					
		4	242	10 40	5·625	6·903	6·793					
		5	221	7 20	8·181	6·684	4)27·525					
		6	230	11 34	5·187							
		Mean	227·33			True mean speed	6·881	4·587	4·486	·101	Negative 2·25	

3rd.	45	1	235	10 45	5·581	7·382	7·254					Screw set at 2 ft. pitch, without the vanes.
		2	213	6 32	9·183	7·126	7·230					
		3	228	11 50	5·070	7·335	7·288					
		4	243	6 15	9·600	7·242	7·363					
		5	240	12 17	4·884	7·484	4)29·135					
		6	254	5 57	10·084							
		Mean	235·5			True mean speed	7·284	4·856	4·648	·208	Negative 4·47	
4th.	45	1	174	13 51	4·332	7·166	7·151					Screw set at 3 ft. pitch, without the vanes.
		2	176	6 00	10·000	7·137	7·123					
		3	166	14 2	4·275	7·109	7·100					
		4	178	6 2	9·944	7·092	7·045					
		5	166	14 9	4·240	6·998	4)28·419					
		6	175	6 9	9·756							
		Mean	172·5			True mean speed	7·105	4·736	5·106	·370	Positive 7·24	
5th.	45	1	116	10 5	5·950	6·132	5·781					Screw set at 4 ft. pitch, with the vanes.
		2	136	9 30	6·315	5·430	5·699					
		3	119	13 12	4·545	5·968	5·690					
		4	112	8 7	7·392	5·413	5·496					
		5	116	17 28	3·435	5·580	4)22·666					
		6	121	7 46	7·725							
		Mean	120			True mean speed	5·666	3·777	4·736	·959	Positive 20·24	

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6th.	46	1	176	[illegible]	[illegible]	[illegible]						[illegible]
		2	179	[illegible]	[illegible]	[illegible]	7·166					
		3	181	[illegible]	[illegible]	[illegible]	6·160					
		4	182	[illegible]	[illegible]	[illegible]	6·344					
		5	178	7 27	[illegible]	[illegible]	7·706					
		6	189	6 44	[illegible]							
							4)27·331					
		Mean	180·83			True mean speed	6·833	4·555	5·858	·708	Positive 14·00	
7th.	45	1	240	9 30	6·315	5·692						Rennie's screw, 6 blades; 23½ in. diameter; 2 ft. pitch.
		2	250	11 50	5·070	6·178	5·935					
		3	222	8 14	7·287	5·530	5·854					
		4	223	15 54	3·773	5·922	5·726					
		5	222	7 26	8·071	5·305	5·613					
		6	200	23 37	2·540							
							4)23·128					
		Mean	226·16			True mean speed	5·782	3·854	4·463	·609	Positive 13·64	

8th.	45	1	195	5 28	10·975	7·005	6·435					Griffiths' screw, 23½ in. diam., 3 ft. pitch, with vanes; set at 10 deg. at boss, and 20 deg. at circumference.
		2	187	19 46	3·035	5·865	5·942					
		3	159	6 54	8·695	6·020	5·597					
		4	160	17 56	3·345	5·174	5·491					
		5	143	8 34	7·004	5·809	4)23·465					
		6	159	13 00	4·615							
		Mean	167·16			True mean speed	5·866	3·911	4·948	1·037	Positive 20·95	
9th.	45	1	184	9 2	6·642	7·546	—	5·030	5·447	·417	Positive 7·65	Vanes set at 5 deg. at boss, and 15 deg. at circumference.
		2	184	7 6	8·450							
		Mean	184									
10th.	45	1	163	7 5	8·470	6·499	6·199					Vanes set at 0 deg. at boss, and 10 deg. at circumference.
		2	164	13 15	4·528	5·900	6·525					
		3	164	8 15	7·272	7·151	6·468					
		4	158	8 32	7·031	5·785	6·311					
		5	163	13 13	4·539	6·838	4)25·503					
		6	164	6 34	9·137							
		Mean	162·66			True mean speed	6·375	4·250	4·815	·565	Positive 11·73	

EXPERIMENTS conducted in RENNIE'S LAUNCH, fitted with GRIFFITHS' SCREW and RIGG'S PATENT DUPLEX PROPELLER—(*continued*).

Date and No. of Trial.	Height of Steam.	No. of Runs.	Revolutions of Engines per Minute.	Time.	Assumed Speed in Knots.	First Mean Speed.	Second Mean Speed.	Corrected Speed in Knots.	Propeller. Speed in Knots per Hour.	Propeller. Slip In Knots per Hour.	Propeller. Slip Per cent.	REMARKS.
6th.	lb	1	176	7′ 27″	8·053	7·776	7·169					Griffiths' screw, cut to 21 in. diameter. Pitch 3 ft. Vanes cut to 21 in. diameter; set at an angle of 30 deg.
		2	179	8 00	7·500	6·562	6·138					
	45	3	181	10 40	5·625	5·715	6·322					
		4	182	10 20	5·806	6·929	7·705					
		5	178	7 27	8·053	8·482						
		6	189	6 44	8·911		4)27·334					
		Mean	180·83			True mean speed	6·833	4·555	5·353	·798	Positive 14·90	
7th.		1	240	9 30	6·315	5·692	5·935					Rennie's screw, 6 blades; 23½ in. diameter; 2 ft. pitch.
		2	250	11 50	5·070	6·178	5·854					
	45	3	222	8 14	7·287	5·530	5·726					
		4	223	15 54	3·773	5·922	5·613					
		5	222	7 26	8·071	5·305						
		6	200	23 37	2·540		4)23·128					
		Mean	226·16			True mean speed	5·782	3·854	4·463	·609	Positive 13·64	

8th.	45	1	195	5 28	10·975	7·005	6·435					Griffiths' screw, 23½ in. diam., 3 ft. pitch, with vanes; set at 10 deg. at boss, and 20 deg. at circumference.
		2	187	19 46	3·035	5·865	5·942					
		3	159	6 54	8·695	6·020	5·597					
		4	160	17 56	3·345	5·174	5·491					
		5	143	8 34	7·004	5·809						
		6	159	13 00	4·615							
		Mean	167·16				4)23·465					
						True mean speed	5·866	3·911	4·948	1·037	Positive 20·95	
9th.	45	1	184	9 2	6·642	7·546	—	5·030	5·447	·417	Positive 7·65	Vanes set at 5 deg. at boss, and 15 deg. at circumference.
		2	184	7 6	8·450							
		Mean	184									
10th.	45	1	163	7 5	8·470	6·499	6·199					Vanes set at 0 deg. at boss, and 10 deg. at circumference.
		2	164	13 15	4·528	5·900	6·525					
		3	164	8 15	7·272	7·151	6·468					
		4	158	8 32	7·031	5·785	6·311					
		5	163	13 13	4·539	6·838						
		6	164	6 34	9·137							
		Mean	162·66				4)25·503					
						True mean speed	6·375	4·250	4·815	·565	Positive 11·73	

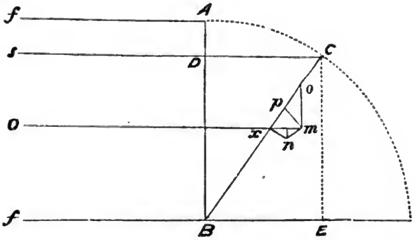
ART. XVI.—*The following excellent little Essay on the Resistance of Fluids is taken from the Encyclopediæ Edinensis.*

WHEN a body is moved through a fluid, such as water, a force is required to overcome the resistance thereof. The same, or a similar force, is required to retain a body at rest, floating in a fluid in motion; in either case the fluid heaps up, or accumulates, in front of the floating body, until the increasing pressure in all directions produced by this accumulation is sufficient to remove sideways that portion of the fluid intercepted by the floating body, and which afterwards falls into the general current. The effect of this accumulation on the bows has been called the *plus pressure.* Again, the fluid, after passing, will require some time and force to fall in towards the after-part or stern of the floating body: this deflection is also caused by some force or hydrostatic pressure—viz., by the water at the stern being somewhat below the level of the passing stream. A portion of the stern, therefore, is not pressed upon by the same force as the bow, even reckoned from the general level of the stream, and independently of the accumulation at the bow; and therefore this depression increases the power or resistance of the fluid, by a quantity which has been called the *minus pressure,* or stern resistance. Lastly, the fluid in passing along the side of the floating body is subjected to a certain degree of adhesion or friction, which increases with the extent of surface.

According to the common theory of the impulse of fluids, it is assumed that each particle of the fluid in motion will strike a solid body in its path in the same manner, and with the same force, as in the collision of hard bodies in free space; therefore, since the number of particles striking in a given time will be as the velocity, and the force of each particle also proportional to the velocity, we have—

1st. The resistance or impulse is as the square of the velocity.

2nd. The number of particles, and consequently the resistance, will be as the density of the fluid and the magnitude of the surface impinged on



Again, in oblique impulses, let $A\,B$ be the plane exposed to direct impulse $f\,A$, $f\,B$; and $B\,C$ the same plane exposed to oblique impulse in the same fluid. The number of particles intercepted by $B\ C$, will be only as $D\,B$ or $C\,E$, that is the sine of the angle of incidence $O\,x\,B$; but also the perpendicular action of each particle o, as Om, will be diminished in the ratio of xm to $xn = B\,C : C\,E$, that is, as the sine of incidence; so that we have,

3rdly, The direct resistance or impulse is to the oblique effective impulse as the square of radius to the square of the sine of incidence.

From these principles Newton determined that the impulse on a cylinder is $\frac{2}{3}$ that on the transverse section through its axis, and that the impulse on a sphere is $\frac{1}{2}$ that on its great circle.

In like manner, from the same principle, it has been deduced, that the resistance or direct impulse of an inelastic fluid on any plane surface is equal to the weight of a column of the fluid whose base is equal to the surface struck, and height equal to twice the fall required for producing a velocity equal to that with which the plane moves in the fluid. In elastic fluids the impulse is double of the above ("Principia," vol. 2, p. 35, 38). It does not, however, appear that the theory of resistance here given, from Newton's investigations, is at all accordant with experiments; but since we have as yet no better to direct our researches, we may endeavour to modify it only so far as the numerous experiments made on the subject may require. In fact, the action of a fluid on any solid body cannot at all be considered as that of a number of hard particles striking it, and then thrown off into free space; for the mobility of the fluid, and the property it possesses of rising above the level (if like water), or of being compressed (if like air), gives it all the properties of an elastic body, and makes its action on the solid that of a simple pressure, the amount of which may be readily measured by that accumulation. This accumulation becomes, in its turn, a moving power, impelling the parts of the fluid below it to escape in all directions, and of course communicating a motion transverse to the general direction of the stream, or rather, perhaps, along the surface of the fluid, and with an increased velocity. The figure of that surface, and its adaptation to the natural path, followed by the filaments of water in passing round and closing in behind the body, greatly affect the observed resistance.

With respect to the agreement of experiments with the above principles, it has been found that the resistance increases nearly as the square of the velocity, little deviation appears in the smaller velocities, and Newton has shown, that by subtracting a certain uniform quantity for the adhesion of the fluid, the remainder agreed exactly with the theory; and that in the greater velocities there is a deviation arising from the inertia of the fluid which accumulates in front, and is rarefied or depressed behind the body.

According to Borda's experiments the resistance to the surface of

		Ratio of Theory to Experiment.
3^2 or 9 inches, being...	9	= 1 : 1
4^2 or 16 — was ...	17.535	= 1 : 1.096
6^2 or 36	42.750	= 1 : 1.168
9^2 or 81	104.737	= 1 : 1.294

In larger surfaces, the deviation would probably be much greater, as the smaller afford greater facility of escape. The only two fluids of different densities which it is necessary for us to inquire into with reference to their powers of resistance, being air and water, we shall confine ourselves to them, and for the first, it appears from the experiments of Mr. Robins, that the resistance of a square foot of air moving with the velocity of one foot per second on 16 inches, is ....·001596lb.

By Borda's experiments the resistance
on 16 inches, is ....·001757lb.
On 81 inches ....·002042lb.

Bouguer has calculated that the impulse of sea-water, with a velocity of 1 foot per second, is 23oz. on a square foot, French measure, and that of wind is the same when blowing 24 feet per second. This last velocity would rather be $\sqrt{900} = 30$ feet, if we were to take the density of the air to determine it.

The experiments of the French Academy make the resistance to a square foot moving 2·56ft. per second, to be 7·625lb.; or, in English measures, 1·136 square feet moving 2·7263ft. per second, gives a resistance of 8·234lb. avoird., which is nearly the weight of a column of water of this base, having its height equal to the fall necessary for communicating this velocity, and only $\frac{1}{2}$ the resistance assigned by the Newtonian Theory. If we calculate from the last number, the impulse on 1 square foot moving 1 foot per second, we have 0·973lb. avoird. Much, however, depends on the form and situation of the adjoining parts. The experiments of the Academy were made on a prism or box 2ft. square and 4ft. long. The resistance on a thin board, of the size of the end of this box, would have been greater. Thus, according to Buat, the resistance on a square foot, wholly immersed in a stream, was—

A square foot as a thin plate	1·81lb.
Ditto, as the front of a box 1 foot long	1·42
Ditto, as ditto, 3 feet long	1·29

Sea-water about $\frac{1}{25}$ greater.

The resistance to sailing vessels is, therefore, considerably less in the direction of their length than in that of their breadth, upon equal portions of surface, while the resistance to their surface of sail or an oar is the greatest possible. Both these properties are to be appreciated.

We may, therefore, assume that the resistance of water in sailing vessels is about 1·5lb. per square foot, moving 1 foot per second, and that the impulse on a sail is ·002lb., or $\frac{1}{500}$lb. for the same surface and velocity;—proportions not very distant from that of their relative densities, when modified as before mentioned.

If we estimate the resistance for a velocity of 1 nautical mile per hour, we shall have air per square foot ·005lb., and water per square foot 4·17lb.

However, the bows of vessels are never made square, and the sails are most frequently placed obliquely. Theory, in this instance, appears at variance with experiments. The best experiments hitherto made in this department of our subject are those of the French Academy. A box, of 3 feet square and 4 long, was made and fitted with prows of a wedge-like form, the angles of which varied by 12° in each set of experiments from 12° to 180°, so that the angles of incidence varied 6° from each other. These boxes being immersed 2 feet in a large basin of water, were drawn obliquely by a line and weights, the motion after a little time becoming very uniform. The time of passing over 96 French feet was then carefully noted, and the resistance calculated from the weight employed, after deducting a certain quantity for friction and the accumulation of water on the anterior surface. The following table exhibits the result of these experiments. Col. 1 is the angle of the prow; col. 2 the angle of incidence; col. 3 the observed resistance; col. 4 the resistance calculated from col.

1 as the squares of the sines of incidence; col. 5 the same reduced as the sines only of incidence:—

Angle of Prow.	Angle of Incidence.	Impulse observed.	Square of Sine.	Sine only.
180°	90°	1000	1000	1000
168	84	989	989	995
156	78	959	957	978
144	72	908	905	951
132	66	845	835	914
120	60	771	750	866
108	54	693	655	809
96	48	615	552	743
84	42	543	448	669
72	36	480	346	587
60	30	440	250	500
48	24	424	165	407
36	18	414	96	309
24	12	406	43	208
12	6	400	1	105
1	2	3	4	5

The error of the theory is as important in the action on *sails;* for the experiments of Borda and Robins on the oblique impulse of air are very conformable to those of the Academicians on waters, and the neat experiments of the Society for the improvement of Naval Architecture exhibit similar results. We may therefore observe, that the oblique impulse of the wind is much more efficacious in preserving the ship in the direction of the course than they would suppose; and, in the same manner, the oblique action of the water is more efficacious in resisting lee-way.

From the experiments of the Society for the Improvement of Naval Architecture, it would appear, that in the ordinary velocities, the total resistance of sharp-ended vessels is little more than one-third of those with square ends. The impression of the wind being at the same time more, we are justified, at least, in calculating for velocities of five miles per hour, or upwards, in assuming a pressure of only five pounds per square foot of the cross section of the vessel for a velocity of one foot per second.

Power of Sails.—From the preceding data we may proceed to calculate the rate at which a vessel may pass through the water, her own dimensions and those of her sails being given.

Case 1. The ship sailing before the wind: let the breadth $= b$. draft of water $= d$, the area of sail $= a$. Let $p =$ the pressure of the wind at one foot per second, $q =$ pressure of water on one square foot at one foot per second,

$w =$ velocity of the wind
$v =$ velocity of the ship passing through the water.

The ship sailing before the wind, we have the velocity with which the wind strikes the sails $= w-v$, and the impulse on the sails $= \overline{w-v}|^2 \, p\, a$. The resistance of the water on the ship will be $b\, d\, q\, v^2$,
Hence, when the motion has become uniform, we have,

$$\overline{w-v}|^2 \, p\, a = b\, d\, q\, v^2$$

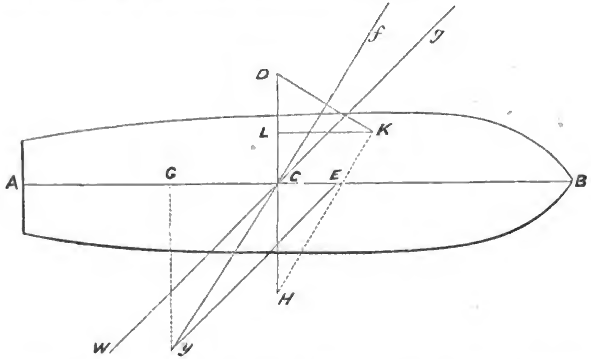
$$\overline{w-v}|^2 = \frac{b\, d\, q\, v^2}{p\, a}$$

$$\therefore w = v + v\sqrt{\frac{b\, d\, q}{a\, p}} = \left\{1 + \sqrt{\frac{b\, d\, q}{a\, p}}\right\} v$$

The velocity v of the ship therefore will be,

$$v = \frac{w}{1 + \sqrt{\frac{b\, d\, q}{a\, p}}}$$

Case 2. As to the motion of a vessel in a side wind, the problem is somewhat more complicated.



Suppose *AB* to be the keel, *C* the centre of the mast, *DH* the yard, trimmed square, *WC* the direction and velocity of the wind, and *CE* the velocity of the ship. Then, relatively to the ship, the direction of the wind on the sail will be in the diagonal *yC*, and *Cf* will be the direction of her vane when in motion, though *Cg* will be its direction when at rest: this apparent change or heading of the wind when a ship is in motion is familiar to seamen. Now since the wind *yC* acts obliquely on the sail *DH*, we must reduce its direct impulse in the ratio of the square of the sine of obliquity. Draw *HK* parallel to *yC*, and *DK* $\perp^{r}$ to *HK*; also draw *KL* $\perp^{r}$ to *DH*, then *DK* will be as the number of particles striking the surface of the sail, and the perpendicular action will be represented by *KL*. The other portion of that force acting parallel to the face of the sail, and $\perp^{r}$ to the keel, can have no effect on the progressive motion of the ship, except that its friction, or the bagging of the sail, may tend to carry the vessel to leeward, which we do not at present consider, looking on the sail as a plain surface. Draw the $\perp^r$ yG, then CG is the sine of obliquity yCH, and the impression of yC is as the square of CG.

Preserving the same notation as before, we have $CE=v$, $WC=w$, $EG=w$, $sin\ Gy\ E=w.\ sin\ WCH$, and $CG=EG-EC=\ w.\ sin\ WCH-v$; and since the impulse $=a\,p\left\{w\ sin\ WCH-v\right\}^2$, where $a=$area of sail, and p the impulse on the square foot, we have,

$$a\,p\left\{w.\ sin\ WCH - v\right\}^2 = b\,d\,q\,v^2$$

$$\text{and } w.\ sin\ WCH = \left\{1+\sqrt{\frac{b\,d\,q}{a\,p}}\right\} v$$

$$\text{and } w = \frac{\left\{1+\sqrt{\frac{b\,d\,q}{a\,p}}\right\}}{sin\ WCH} \times v$$

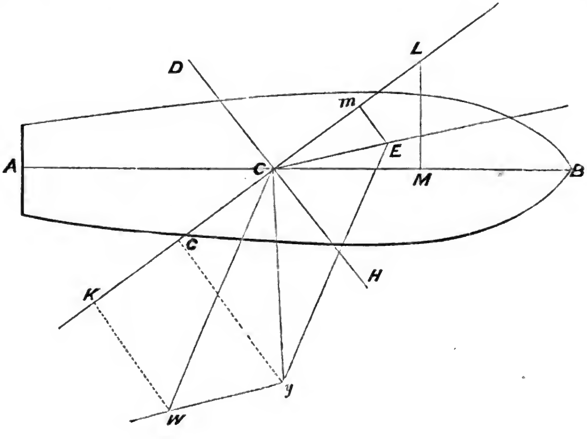
$$\text{or } v = \frac{w.\ sin\ WCH}{1+\sqrt{\frac{b\,d\,q}{a\,p}}} = \frac{w.\ sin\ WCH\ \sqrt{ap}}{\sqrt{a\,p}+\sqrt{b\,d\,q}}$$

which is precisely the former result, reduced by the sine of obliquity.

In either of these cases, it may be perceived that the coefficient of v being constant, w and v are proportional to each other, and the velocity of the ship with the same sail is proportional to the velocity of the wind. But the quantity a, expressing the area of sail, being under the radical sign, the velocity of the ship, the wind remaining the same, will be as the square root of the area of sail; so that to procure a double velocity, four times the area of sail is required.

Case 3. But it is not usual to keep the yards square when the wind is oblique to the course; a considerable portion of the wind that might be intercepted would be lost; and if the wind were before the beam, the sails would be taken aback. Besides, ships exposing more surface of sail when their sides are exposed to the wind, are enabled to make up for the loss of power occasioned by the obliquity of action.

Let the sail *DH* be trimmed obliquely: it is evident, that since the impulse of the wind must be perpendicular to the sail, the vessel will not move in the direction of her length *AB*, but in some other line to leeward of it, as *CE*. Her head therefore must be kept to windward of her intended course: the amount of this deviation—viz., the angle *BCE*, is called the lee-way. If the ship were a round tub, to be equally moveable in all directions, and fitted with a mast and sail in the centre, it is clear that if prevented from turning round, it would move in the direction *CL* perpendicular to the yard. But being from the construction much more easily moveable in the direction of the length than the breadth, the course of a ship will be somewhere between *CL* and *CB*; and whatever be the amount of the impulse on the sail



in the direction *CL*, the angle of lee-way *BCE* will remain the same, for the impulse of the resisting surfaces will still be proportionate; and this impulse must be in the direction *CL*, so long as the yard remains in the same trim. Whatever may be the direction of the wind, it follows, therefore, that the lee-way depends on the shape of the vessel and trim of the sails, not considering the effect produced by the action of the wind on the hull and rigging, which, when the quantity of sail carried is small, becomes a very important part of the whole impelling power. If we knew the proportionate resistance made to longitudinal and transverse motion, we could ascertain the lee-way for any angle of impulse. But we have seen that the resistance on the sides, if calculated according to the theory, would not present us with a true result, since the action of the fluid on them in this case would be very oblique. In common vessels besides, the form cannot be reduced to an equation, and the surfaces of action change with every variation in the direction of the impelling power. As matter of fact it is known that a good-sailing ship, with all her sails in action, will not make more than from 5° to 12° lee-way. The amount increases as she is obliged to take in her sails, and in the shallow vessels employed in inland navigation, the lateral resistance being less in proportion, the lee-way must in general be greater. Hence the adoption of lee-boards, sliding knots, &c., which increase the lateral resistance, without diminishing much the direct motion. But to proceed in the investigation before us, take *CE* to represent the motion of the ship, *WC* that of the wind, then the diagonal *yC* will be the relative direction and force of the wind on the sail *DH*, and its impulse, as in the former case, will be represented by the square of CG. Draw the perpendiculars $m\,E$ and WK; then, because of parallels, $m\,C = GK = EC.\ sin\ ECH$, and $CK = CW.\ sin\ WCB$; and with the former notation $EC = v$, $WC = w$; then $CG = CK - GK = w.\ sin\ WCH - v.\ sin\ ECH$; and the impulse on the sail will be—

$$a\,p\left\{w.\ sin\ WCH - v.\ sin\ ECH\right\}^2$$

Now the vessel moving uniformly, this impulse will be equal and opposite to that produced by the resistance to the ship's side, in the direction LC, when the ship is moving with the velocity and direction CE. Let CL represent this impulse, or that of the wind on the sail, and resolve it into CM and ML, of which CM will represent that part effective in the direction BA, and ML that in the transverse direction, when sailing with the lee-way LCE: putting s = surface or side of the ship exposed to the action of the water in the direction CL; $q\,s$ will be the impulse of the water on it—

$$\text{and } a\,p\left\{w.\ sin\ WCH - v.\ sin\ ECH\right\}^2 = q\,s\,v^2$$

$$\text{or } w.\ sin\ WCH = v\left\{sin\ ECH + \sqrt{\frac{qs}{ap}}\right\}$$

$$\text{and } w = v\left\{\frac{sin\ ECH + \sqrt{\frac{q\,s}{a\,p}}}{sin\ WCH}\right\}$$

$$\text{or } w : v = sin\ ECH + \sqrt{\frac{q\,s}{a\,p}} : sin\ WCH$$

Where, by diminishing ECH, that is, by trimming sharp, and enlarging a the quantity of sail in proportion to s the side exposed to the water, the third term of this proportion may be *less* than the fourth, and consequently the velocity of the ship may exceed that of the wind.

ART. XVII.—*Miscellaneous.*

WE have reason to believe that Mr. Seely has during the recess followed up his investigations into Admiralty accounts and other matters, and that the question of Admiralty Reform will again be brought before the House.

His Grace the Duke of Somerset, First Lord of the Admiralty, has intimated that the Admiralty are immediately to furnish twelve Training Frigates, for the supply of boys for the navy! His Grace has taken this course in consequence of the difficulty experienced in manning merchant ships in the port of London; it having been found impossible during many months to obtain a greater proportion than one British sailor in six, although the Merchant Shipping Act requires that two-thirds of the crew shall be British seamen. We think that naval critics would like the difficulty met in a more comprehensive manner.

We understand the Woolwich and Waterman Steam Packet Companies have selected a design from some one hundred or more which had been sent in, in reply to their advertisement. They now propose merely returning the other designs without any inspection by the contributors and the public, as is usual on such occasions. We are informed several contributors are much dissatisfied with this unusual course. We hope, therefore, the directors will put themselves to a little trouble and expense, so as to afford the contributors the opportunity of inspecting all the designs. We shall recur to this subject in our next number.

ART. XVIII.—*Launches in October.*

October 2nd, 1865, from the yard of Messrs. W. Simons and Co., Renfrew, screw-steamer *Mahratta*, for the Netherlands Steam Navigation Company. Length between perpendiculars, 220 feet; breadth extreme, 28 feet; depth of hold, 17 feet; tonnage O.M., 900 tons; register tonnage, 742; draught of water, 15 feet; nominal horse-power, 120.

On 4th October, from the yard of Mr. James Robinson at Pallion, a brig. Length of keel and fore rake, 93 feet; beam, 24 feet 3 inches; depth of hold, 13 feet 6 inches; tonnage N.N. measurement, 190 tons; classed A 1 for eight years at Lloyd's.

October 5th, from the yard of Messrs. Robert Duncan and Co., Port Glasgow, screw-steamer *City of Aberdeen.* Length between perpendiculars, 220 feet; beam, 29 feet; depth moulded, 17 feet; register tonnage, 682; builder's tonnage, 900 tons; capacity for cargo, 550 tons; dead weight at 13 feet; draught of water; horse-power, 170. Engines by Messrs. Blackwood and Gordon.

October 5th, from the yard of Messrs. Henderson, Coulborn, and Co., Renfrew, screw-steamer *Kinsale,* for the Glasgow Screw Steam Shipping Company. Length between perpendiculars, 187 feet 6 inches; beam, 25 feet; depth moulded 15′ 4″; builder's tonnage, 611$\frac{66}{94}$ tons; 500 tons register; capacity for cargo, 29,500 cubic feet; will carry 510 tons; dead weight at 13 feet draught of water. Engines by Messrs. Henderson, Coulborn, and Co., of 95 nominal horse-power.

On the 5th October, 1865, from the yard of Messrs. Todd and McGregor, Glasgow, paddle-wheel pleasure yacht, *Faid Zafar,* for his Highness the Viceroy of Egypt. Length between perpendiculars, 220 feet; breadth moulded, 20 feet; depth moulded, 9 feet; tonnage B.M., 442$\frac{52}{94}$; draught of water, 3′ 6″ mean. Engines of 130 nominal horse-power, by Messrs. Todd and McGregor. The vessel and engines are built of steel.

On the 5th October, from the yard of Messrs. W. Pile, Hay, and Co., Sunderland, sailing-vessel *Star of the South.* Length between perpendiculars, 177′ 5″; beam, 30′ 7″; depth moulded, 18′ 6″; register tonnage, 665 tons; builder's tonnage, 800 tons; capacity for 1,200 tons cargo; draught of water, 8 feet light, 17 feet loaded.

On 5th October, from the yard of Messrs. Alexander Hall and Co., Aberdeen, missionary barque *John Williams.* Length between perpendiculars, 130 feet; beam, 25 feet; depth moulded, 16 feet 2 inches; builder's tonnage, 357 tons; register tonnage, 296; draught of water, 7 feet 6 inches light, 13 feet 4 inches loaded.

On 6th October, from the yard of Messrs. Barclay, Curle, and Co., Glasgow, screw-steamer *Avon*, for the Carron Company's London and Grangemouth trade. Length, 190 feet; beam, 28 feet; depth of hold, 15 feet; tonnage O.M., 722 tons; gross register, 572 tons; will carry 720 tons dead weight on 14 feet draught of water; classed A B 1 at Lloyd's; engines, direct acting, 120 nominal horse-power.

On 7th October, from the yard of Messrs. Maudslay, Sons, and Field, of Lambeth and East Greenwich, the *Lady Derby* screw steamer for the General Iron Screw Collier Company, constructed on Henwood's dynamical principle. Length between perpendiculars, 175 feet 6 inches; breadth moulded, 27 feet 6 inches; depth moulded, 18 feet; mean load draught, 15 feet 1 inch; tonnage B.M., $639\frac{25}{94}$; gross register tonnage, 530; classed A B at Lloyd's; capacity of hold for cargo, 800 tons; engines of 90-horse power.

On 10th October, from the Millwall Iron Works and Shipbuilding Yard, twin screw-steamer *Honfleur*. Length between perpendiculars, 160 feet; beam, 23 feet; depth moulded, 12 feet; register tonnage, 300 tons; builder's tonnage, 412 tons; capacity for cargo, 200 tons; nominal horse-power, 100.

On 10th October, from the Millwall Iron Works and Shipbuilding Yard, screw-steamer *Celt*. Length between perpendiculars, 265 feet; beam, 34 feet; depth moulded, 26 feet 9 inches; register tonnage, 1,400 tons; builder's tonnage, 1,504 tons; capacity for cargo, 900 tons; load draught, 18 feet.

On 18th October, from Messrs. Mills's yard, Sunderland, the barque *Isabel*. Length between perpendiculars, 121 feet; breadth extreme, 27 feet 2 inches; depth of hold, 17 feet; tonnage B.M., 438; register tonnage, $394\frac{25}{100}$; classed A 1: 13 years at Lloyd's.

ART. XIX.—*Trial Trips.*

OCEAN RACE BETWEEN THE "FIERY CROSS" AND "SERICA."—The *Fiery Cross* was built at Liverpool, in 1860, of wood. Her dimensions are—length 185ft., beam 31·7ft., depth 19·2ft., tonnage 888 B.M., 689 register, classed at Lloyd's A 1: 13 years.

The *Serica* was built at Greenock, in 1863, of wood. Her dimensions are—length 185·9ft., beam 31·1ft., depth 19·6ft.

The *Fiery Cross* was commanded by Captain Robinson, the *Serica* by Captain G. Innes; both vessels left Foo-choo-foo together, the same tug having towed them both to sea and cast them off at the same time. The voyage from Foo-choo-foo to the Thames is about 25,000 miles, and was performed in 106 days. The sailing qualities of the *Serica* are reported as being superior in strong winds and heavy weather; the *Fiery Cross* excelling in light weather. Both vessels arrived off the Isle of Wight almost simultaneously. The *Taeping* is reported to have performed the same voyage a little later in 102 days, the quickest passage this season. The *Taeping* is an iron-framed vessel planked with wood, built at Greenock in 1863. Length 183·7ft., beam 31·1ft., depth 19·9ft., and 776 tons register, classed A 1: 14 years at Lloyd's.

In a letter to the *Standard*, however, "J. B." claims that the *Young Lochinvar* is a better ship, and would have made the voyage, under as favourable state of the wind, in two days less than the *Taeping*. The *Young Lochinvar* is a wooden vessel, built at Greenock in 1863. Length 181·7ft., beam 31·1ft., depth 19·8ft., 724 tons register, and classed A 1: 13 years.

There is but little difference in any of them as to dimensions. The *Serica*, *Taeping*, and *Young Lochinvar* were built by Messrs. Steele and Co.

From such spirited trials as these the greatest benefit might result to naval architecture and navigation, were their performances accurately and scientifically recorded, with the known elements of each ship

An interesting trial of her Majesty's ships *Helicon* and *Salamis*, as to speed and sea-going qualities, has taken place, lasting, we believe, three days, but not, we consider, under the most favourable circumstances as regards the *Salamis*, as we understand, her boilers and tubes, were not in so satisfactory a state as those of the *Helicon*. The *Helicon* and *Salamis* were both from the designs of Isaac Watts, Esq., C.B., the *Helicon*, however, having been since altered from midships forward to Mr. Reed's views, and her boiler power increased; her dimensions are—

	Ft.	in.
Length	220	0
Breadth	28	$2\frac{1}{2}$
Depth in hold.............................	14	6
Tonnage	$836\frac{42}{94}$	B.M.

This trial was evidently intended to test the merits of Mr. Reed's bow in the *Helicon*. It is stated "they did not encounter very heavy weather, and when both were steaming 9 and 10 knots, the *Salamis* flung sheets of spray over the bows in the usual manner, but shipped *no* 'green seas.' The *Helicon*, with her longer bow, rode the waves generally with greater ease so long as she kept her head up well, and passed the seas away under her" (what this means we don't exactly understand); "when, however, the *Helicon* dipped her bows deeper in the waves than usual, then she proved much inferior to the *Salamis*, in disposing of the opposing seas, for, unable to get rid of the weight of water hanging on her inclined bows, she flung it bodily 'in-board' in 'green seas,'" and this in "no really heavy head seas."

So far, then, the *Salamis* proved herself the better "sea-going vessel."

On the return run of about 350 miles, in which both were to make their way back as fast as possible —in fact, a *race* back; the *Helicon* started before the *Salamis*, and "obtained a lead of 2½ to 3 miles: the *Helicon* arrived first, 12½ minutes before the *Salamis;* but from this we must deduct the 2½ to 3 miles start, the greater boiler power, which, we understand, is some 250 I H.P., the better condition of her boilers and tubes. If, then, these statements which we extract from the *Times* are correct, the *Salamis* has, without doubt, proved herself the faster and better sea-going vessel.

TRIAL TRIP OF H.M. TURRET-SHIP "WYVERN" on 5th October, with all her sea-going weights on board, the absence of her guns and ammunition, which have not yet been supplied to her, being compensated for by 180 tons of iron ballast, placed in her turrets. Under these conditions—the only conditions that can give a fair estimate of a vessel's sea-going rate of speed—the *Wyvern's* draught of water was 14 feet 8 inches forward and

16 feet 1 inch aft, or a mean draught of 15 feet 4½ inches; immersion of the upper edge of the upper screw blade, 2 feet 10½ inches. The forecastle deck was then, at the supernumerary stem-head, 15 feet 9 inches above the water-line, the poop deck at the stern being 12 feet 6 inches, and the bulwarks amidships being 9 feet 10 inches. The poop and forecastle, being built up as superstructures on the hull proper of the ship, stand 8 feet above the level of the upper deck, and the depth of the midship bulwarks is 5 feet. It follows from this, therefore, that the hull proper of the *Wyvern* floated 4 feet 10 inches from the water-line in amidships, with a slight rising sheer forward and aft, but that she made her trial on Thursday as a temporarily fitted sea-going cruiser with a roomy poop and forecastle connected by deep bulwarks. Had she made her trial with her upper deck fittings swept away, leaving nothing above the deck but her turrets, funnel, and pilot-house, she would have made her trial as a veritable Monitor, but a Monitor having her turret bases submerged, with their weight-spread over a large area, and superior in every way to the American Monitor type.

The results of the trials, at full and half boiler power, turning circles, &c., were as follows:—

FULL-BOILER POWER RUNS.

No. of Run.	Time. M. Sec.	Speed. Knots.	Rev. of Engines.	Steam. lb.	Vacuum. Inches.
1	5 27	11·009	67	19	24
2	6 45	8·889	67	20	23
3	5 25	11·077	65	18	24
4	6 38	9·043	66½	21	23
5	5 12	11·588	68	21	23
6	7 20	8·182	66	21	23

Mean speed of the ship at full-boiler power, 10·060 knots.

HALF-BOILER POWER RUNS.

No. of Run.	Time. M.	Time. Sec.	Speed. Knots.	Rev. of Engines.	Steam. lb.	Vacuum. Inches.
1	5	25	11·077	55	20	23
2	9	54	6·061	55½	16	23½
3	5	38	10·651	54½	18	23
4	8	34	7·004	54	19	23

Mean speed of the ship at half-boiler power, 8·523 knots.

The indicated horse-power of the engines was 1,440, with excellent indicator card diagrams.

Circles.	Port Helm.		Starboard Helm.	
	Full Power.	Half Power.	Half Power.	Full Power.
Time in getting helm up	50″	30″	32″	58″
Turns of wheel ...	4	4	4	4
Men at wheel	8	8	8	8
Half circle made ...	2′ 25″	2′ 33″	2′ 35″	2′ 34″
Full circle made	4′ 49″	5′ 32″	5′ 47″	5′ 5″
Angle of rudder ...	41°	41°	39°	41°
Revolutions of engines at half circle	61	49	53	61

(The ship's screw has a right-handed thread.)

After making the circles the engines were tested in their quickness of movement, in obedience to order given, and they were stopped dead in 11 sec., from going at full speed ahead, turned astern from rest to full speed in 4 sec., stopped and sent on ahead again at full speed in 11 sec.

The *Wyvern* carries two turrets, both fitted with carriages and ports for two 12-ton guns. They are polygonal in shape, have 22 inches of teak backing between the iron ribs at the back of the armour-plates, with an inner iron skin, and also a wooden sheathing over the latter to lessen the possibility of the bolt nuts and screw ends flying off when the turret is struck by shot. The turret armour is 5½-inch, doubled round the port-holes. Both the turrets are of the same size as the large double-gunned turret of the *Royal Sovereign*, and both have been constructed on Captain Cowper Coles's plans. The winches with which they are fitted for running in and out the guns were also manufactured by the Messrs. Laird from Captain Coles's drawings. The engines of the ship were built by Messrs. Laird, and are of the ordinary horizontal pattern, of 350 nominal horse-power, having two cylinders of 56 inches diameter, with a length of piston stroke of 33 inches. They drive a fixed three-bladed screw, having a diameter of 14 feet 6 inches and a pitch of 20 feet 6 inches. Messrs. Laird Brothers are also the builders of the ship and her sister vessel the *Scorpion*. The boilers of the ship are four in number, with 250 square feet of grate surface and 6,750 square feet of heating surface. The coal bunkers have stowage for 300 tons. The rig of the ship is on the plan designed by Captain Cowper P. Coles, as a barque, the fore and main masts being tripods and the area of sail on the three masts being unusually large for a ship of the *Wyvern's* tonnage. The guns of the ship will train and depress in the same degree as those of her sister ship the *Scorpion*, 80° aft and forward in extreme training, and 4° of depression abeam.

Perhaps the most remarkable feature in the *Wyvern* and *Scorpion* exists in the double qualification they both possess—first, as sea-going cruisers, with their light poops, forecastle, deep bulwarks, and rig all above their armoured hulls; and, secondly, as coasting

Monitor batteries, with all temporary fittings on their upper deck swept away and their guns sweeping over their decks, their turrets glacis, in every direction. In the first respect they are undoubtedly the most valuable, for thus fitted and rigged they are capable of steaming and sailing round the coasts of the three kingdoms in any weather, while the poop and forecastle afford excellent accommodation to the officers and crew. Should it ever be found necessary in time of war to clear the decks, and give both ships their true Monitor form, a few powder discharges from the turret guns would speedily effect the desired metamorphosis.—*Times.*

ART. XX.—*List of Patents from January 1st, to September 18th*, 1865.

29. W. Watson. Propelling Apparatus. Jan. 5.
54. H. Ames. Ordnance. Jan. 6.
83. H. Contanche. Reefing and Furling Sails. Jan. 11.
118. A. and E. Paul. Steering Apparatus and Rudderbrake. Jan. 14.
137. J. Betteley. Shipbuilding. Jan. 16.
148. A. B. Bull. Reefing and Furling Sails. Jan. 18.
210. T. Steel. Lowering and Disengaging Boats. Jan. 25.
233. J. E. Massey. Ships Logs' and Sounding Machines. Jan. 26.
225. J. Harrison. Cleaning Ships' Bottoms at Sea. Jan. 26.
228. J. Hamilton, jun. Propelling. Jan. 26.
235. J. E. F. Lüdeke. Compasses. Jan. 27.

271. M. Henry. Propelling. Jan. 31.
286. J. Hughes Construction of Armour-plated Ships. Feb. 1.
295. J. H Johnson. Ordnance. Feb. 2.
296. J. S. Jeffreys. Armour-plated Vessels. Feb. 2.
292. C. Lungley. Armour-plated Ships, &c. Feb. 2.
337. R. Brassens and F. A. Le Mat. Ships and Vessels. Feb. 7.
365. M. Bier. Propelling Ships, &c. Feb. 9.
372. A. Krupp. Breech-loading Ordnance. Feb. 10.
405. J. G. Tongue Paddle-wheels. Feb. 13.
420. J. Trotman. Mooring Anchors. Feb. 14.
433. C. Lungley. Ventilating Blinds or Screens and in means of Ventilating Ships or Vessels, Feb. 15.
438. G. T. Bousfield. Armour-plated Ships. Feb. 15.
455. J. Brown. Armour-plates for Vessels of War, &c. Feb. 17.
509. G. Haseltine. Ships of War. Feb. 23.
510. J. G. Hughes. Propelling. Feb. 23.
598. Sir J. S. Lillie. Propelling. March 3.
602. L. Thomas. Propellers. March 4.
624. F. Cruickshank. Coating for preventing Fouling in Iron Ships and Structures in sea-water. March 6.
681. R. P. Roberts. Coating the Bottoms of Iron Ships. March 10.
783. W. V. Greene. Vessels of War and Ordnance. March 21.
787. W. Arthur. Apparatus for registering the Course steered by a Vessel during any given period. March 21.
873. T. Glover. Construction of Ships' Yards and Spars. March 28.
871. J. C. C. Halkett. Coating Vessels. March 28.

932. J. Vonder Poppenburg. Projectiles. April 3.
935. W. C. Gillings. Paddle-wheels. April 3.
970. E. Ritherdon. Preventing Iron Ships from oxidation and corrosion. April 5.
1008. G. Davies. Coating Ships. April 8.
10[illegible]3. W. Bedder. Construction of Ships or Vessels. April 18.
1107. H. Caudwell. Construction of Ships of War. April 20.
1118. R. Griffiths. Propelling Vessels. April 21.
1138. R. H. Dart. Propellers. April 24.
1157. E. Elder. Steering Ships. April 25.
1162. W. Husband. Fastening Wooden Planking to Iron Frames in Ships or Vessels. April 25.
1179. S. Harvey. Cutting or shaping Masts, Spars, &c. April 27.
1215. M. W. Ruthven. Propelling Vessels. May 1.
1234. J. B. Fyfe and E. T. Read. Screw Propellers. May 3.
1251. J. Lilley. Ship's Compasses. May 4.
1278. J. C. C. Halkett. Coating Vessels. May 9.
1341. W. Deakin and J. B. Johnson. Ordnance. May 15.
1394. J. Martin. Steering Vessels. May 20.
1481. J. Jopling. Steering Vessels. May 30.
1496. W. A. Brown. Steering Ships. May 31.
1498. T. Summerson. Cupolas. May 31.
1546. G. Haseltine. Fuses and Projectiles for Rifled Ordnance. June 6.
1577. W. H. Harfield. Steering Ships and Vessels. June 9.
1583. D. Spink. Propelling Vessels. June 10.
1612. W. R. Mulley. Sheathing Iron Ships. June 14.
1645. C. Hook and A. Pearce. Propellers. June 19.

1670. W. C. Rickman. Rigging Vessels. June 21.
1731. J Cox. Oars, Paddles, and other Fittings for Boats. June 29.
1752. J Calvert. Propelling Ships. July 1.
1817. C O. Papengouth. Constructing Ships and Vessels. July 8.
1830. F. Massey. Improvements in Ships' Logs. July 11.
1890. C. H. Simpson. Propelling Vessels. July 20.
1899. St. J. V. Day. Propelling Ships. July 21.
1919. J. M. Croft. Steering Ships or Vessels. July 24.
1943. R. Ginman and F. Pulman. Coating Ships' Bottoms. July 26.
1986. W. La Penotière. Coating Ships' Bottoms. Aug. 1.
2010. P. Cato. Fastenings for Ships. Aug. 3.
2014. H. D. Cunningham. Working Guns. Aug. 3.
2041. C. H. Simpson. Sustaining and Lowering Ships' Boats. Aug. 5.
2080. W. T. Cole and H. P. Swift and A. Soares. Propelling. Aug. 11.
2120. S. Parry. Coating Ships' Bottoms. Aug. 16.
2162. D. O. Jones. Cleansing Ships' Bottoms. Aug. 22.
2223. W. Clark. Propelling Vessels. Aug. 29.
2258. R. Davies. Propellers for Ships. Sept. 1.
2316. R P. Roberts. Cleansing Ships' Bottoms. Sept 9.
2374. A. J. Sedley. Propelling Vessels. Sept. 18.
2381. A. V. Newton. Projectiles. Sept. 18.

" TARGET. PLATE 1.

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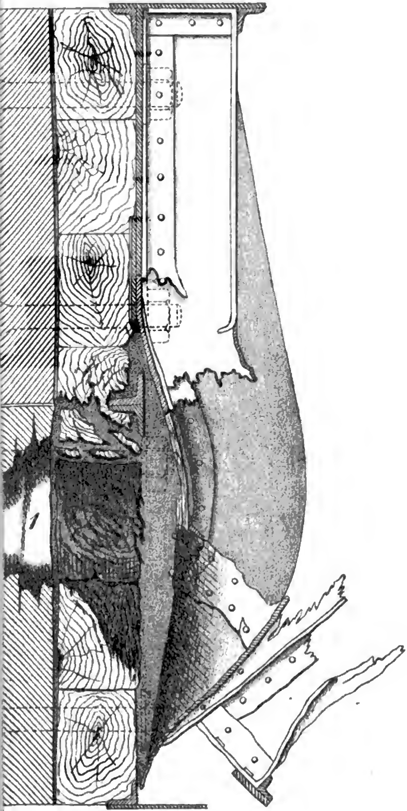
FIG. 2.



SECTION

GUN.

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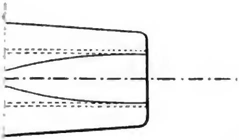

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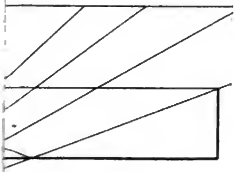
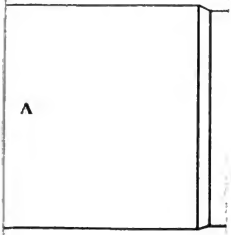


FIG. 4.



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PAPERS

ON

NAVAL ARCHITECTURE,

AND OTHER SUBJECTS CONNECTED WITH

NAVAL SCIENCE.

> "The philosopher may very justly be delighted with the extent of his views, and the artificer with the readiness of his hands: but let the one remember that without mechanical performance refined speculation is an empty dream, and the other that without theoretical reasoning dexterity is little more than a brutal instinct."—*Rambler*, No. 9.

NO. XV.—VOL. IV.

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1865.

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CONTENTS

OF

No. XV.

Page

ART. XXI. A brief Historical Sketch of Guns, Broadsides, and Turrets, with a few Remarks. - 223

XXII. Calculations made on Twenty Ships of the British Navy, with Observations respecting the Forms of some of those Ships. By WM. HENWOOD, Naval Architect, Member of the late School of Naval Architecture. (Being a Reprint from the "United Service Journal" for 1835, and in continuation of the Art. 13, Part 14, Vol. IV. of this series.) - - - - - - 259

XXIII. Description of the Affondatore, Iron Armour-clad Turret Ship, of the Royal Italian Navy. By CHARLES F. HENWOOD, N.A., East India Avenue, London. - - - - 275

XXIV. On Pitching. By the late WILLIAM HENWOOD, Esq., Member of the late School of Naval Architecture. An unpublished Manuscript, dated Malta, 1850. - - 278

Page
XXV. The American Lake Navigation. By HENRY JONES, Esq. - - - - - 287
XXVI. Miscellaneous - - - - - 299
XXVII. Launches in November - - - - 307
XXVIII. Trial Trips in November - - - - 311
XXIX. List of Patents on Naval Subjects - - 318

PAPERS
ON
NAVAL ARCHITECTURE,
&c.

Art. XXI.—*A brief Historical Sketch of Guns, Broadsides, and Turrets, with a few Remarks.*

GUNS.

Gunpowder and cannon, like most other inventions of remote periods, are involved in considerable doubt and obscurity. We are told by Ufano Velasco, a Spanish author, that both were known in China as early as A.D. 85, and there certainly appears to be strong reasons for supposing them to be of Eastern origin, when we reflect that one of the most essential ingredients of gunpowder—namely, saltpetre, is so plentiful in the Oriental parts of the world. In Europe, however, the explosive properties of gunpowder seem to have been first alluded to by the English monk, Roger Bacon, in the year 1280, and it is tolerably well authenticated that in 1320 Bertholdus Swartz, a German monk who practised chemistry, discovered by accident the prodigious expansive force of this composition, for having put a mixture of saltpetre and sulphur into a mortar and covered it with a stone, it took fire and projected the stone with great violence to some distance. This phenomenon caused him to imagine that a similar composition might be applied to warlike purposes. The component parts of gunpowder are charcoal, sulphur, and nitre or marine acid, its specific gravity is about ·868, its elasticity is equally increased by heat and diminished by cold as that of common air, and consequently its weight is the same with the weight of an equal bulk of air at the same elasticity and temperature; and it is concluded that the elastic fluid produced by the firing of gunpowder is nearly three-tenths of the weight of the powder itself, which expanded to the rarity of common air is about 244 times the bulk of the powder. Hence it would follow that the mere conversion of confined gunpowder into elastic vapour would exert against the sides of the containing vessel an expansive force 244 times greater than the elasticity of common air, or, in other words, than the pressure of the atmosphere. But to this is to be superadded all the increase of expansive power produced by the heat generated, which is certainly very intense, though its exact degree cannot be ascertained. Supposing it to be equal to the full heat of red-hot iron, this would increase the expansion of common air (and also of all gases) about four times, which in the present instance would increase the 244 to nearly 1,000, so that in a general way it may be assumed that the expansive force of closely confined powder at the instant of firing is 1,000 times greater than the pressure of common air; and this latter is known to press with the weight of fourteen pounds and three quarters on every inch, the force of explosion of gunpowder is 1,000 times this or 14,750lb., or about 6½ tons on every square inch, and it is proved that the force is more than double this; and modern artillerists reckon the explosive force at about 180,000lb., or about 80 tons on the square inch. This enormous force, however, is diminished in proportion as the elastic fluid dilates, being only half the strength, when it occupies a double space, one third of the strength when in a triple space, and so on. It is reckoned to explode at about 6,000 Fahrenheits' thermometer, but if heated to a degree just below that of faint redness the sulphur will mostly burn off, leaving the charcoal unaltered.

The Germans attribute the invention of cannon to Albertus Magnus, a Dominican monk, in 1250. If this be the fact, it would almost necessarily imply that gunpowder was also known in Europe long before Swartz made his experiment, and even before Bacon had given his hints. It seems most probable, however, that Swartz was the inventor of both, and the figure and name of mortars given to a species of old artillery used for throwing great stone balls at an elevation very much favours this conjecture.

Mariana in his history of Spain says that in 1343, when the Castilians laid seige to Algesiras, at that time in possession of the Moors, the latter made use of cannon with which they desolated the camp of the besiegers, and ruined their works with a terrible noise and still greater astonishment. This is the first time, says he, "that powder and cannon, an invention then new, are mentioned in our history, and of which the ancients never had any notion or use."

According to the same authors, we find that the French had cannon in 1338 under Philip VI.

The first well authenticated application of gunpowder to military purposes in the field seems to have taken place in the year 1346, at the memorable battle of Cressy, where some pieces of cannon were used by Edward III. with much effect. It is also related by historians that his antagonist, Philip de Valois, had left his artillery behind in the hurry and confusion of his march.

The Venetians were also amongst the first who used guns; for at the siege of Chioggia in 1366, they had a species of mortar or cannon, which two Germans had brought, together with some powder and leaden balls. All Italy is said to have exclaimed against this novel method of destruction as a manifest violation of the laws of war.

The first introduction of cannon into naval warfare is to be ascribed to the Spaniards. In a sea-fight with the English and the people of Poitou, near the port of Rochelle in 1372, they had the great advantage of having guns on board their ships.

The more general introduction of cannon into naval combats was, however, effected by the Venetians, who, at the latter part of the fourteenth century, when they were engaged in a maritime war with their rivals the Genoese. A contest of such duration, vicissitude, and obstinacy on both sides was well calculated not only to produce improvements in the usual weapons of annoyance of the period, but also to call forth all the inventive powers of those engaged, in devising means of attack and defence at once novel and terrific. It is not therefore surprising that cannon, then so recently introduced into military warfare, should have

Plate 1.

Sketches of Ancient Pieces of Ordnance

Fig. 1.

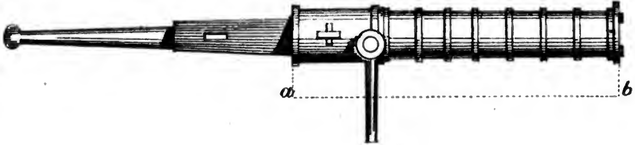


Fig. 2.

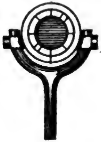


Fig. 3.

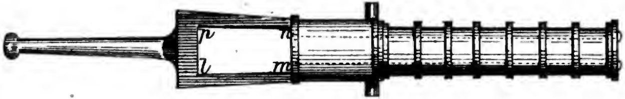
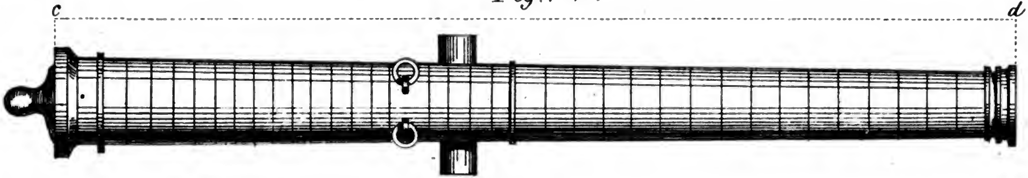


Fig. 4.



been so soon called to the aid of one or other of those powerful States in their dispute for naval pre-eminence.

When guns were first used in naval actions at the time we have just mentioned, they were mounted at the two extremities of the Galleys so as to fire over the prow and stern in a fore and aft direction.

The first guns were but small, and their shot, as we have already mentioned, made of lead; they were either manufactured of iron bars laid lengthways and kept together with strong iron hoops, or of thin sheets of iron rolled up together and hooped. The latter method is illustrated by the following sketches of two ancient pieces of artillery, which are, we believe, still in the Royal Military Repository at Woolwich.

Figs. 1, 2, and 3, Plate I., are respectively the side, front, and horizontal views of a piece of ordnance whose bore is about three inches in diameter and length from *a* to *b* 2 feet 10 inches. It appears to have been loaded at the breech, a plug of iron being driven in upon the charge and secured by wedging it from the part *p l* of the iron frame *p l m n* attached to the breech.

The gun, Fig. 4, Plate I., is in length from *c* to *d* 8 feet 5 inches, and has a bore of about 4 inches. It is composed like the first of sheets of iron rolled up and welded together to form the bore, and then hooped over with iron hoops varying from 2 to 3 inches in breadth. It will be perceived that the form is nearly cylindrical, and there is an attempt at ornament in making some of the hoops thin and projecting in some places. The breech is permanently closed by a plug and cascable of brass, and consequently the gun must have been loaded from the muzzle.

In both of these pieces there are trunnions, the use of which seems coeval with the invention of cannon. They are placed so as to have their upper parts in a line with the axis of the gun, and, as in Fig. 2, it is sometimes inserted in an iron crutch, similar to those used in mounting the swivel gun. At 5 inches from the trunnion in Fig. 4 there are a couple of rings, which were probably used for lifting the piece when required, or for lashing it down to its carriages, which was nothing more than a skid or block of wood hollowed out to receive it. In fact, even in the time of Henry VIII., most of the lighter species of ordnance used on board ships were mounted in this rude manner.

The method of manufacturing cannon just described was laid aside when their use became more general. They were then cast of what is called gun metal, and generally of an extraordinary size, the shot being a stone. At the siege of Constantinople in 1452, the Turks had some which carried shot of 500lb. weight; these, however, seldom stood two discharges without bursting. Many other large and unwieldy pieces, carrying shot of 80, 90, and 100 lb., are mentioned in history.

As a proof that the use of artillery on board ships, or, as they were then termed, Galleons, had soon become pretty general, at the same siege of Constantinople a squadron, composed of one Imperial and four Genoese ships, ventured to attack and defeated with great slaughter the whole Turkish fleet, and their success was in a great measure owing to the effects of their artillery.

It has been already mentioned that at the first introduction of cannon into naval combats they were confined to the two extremities of the Galleys, where they could not interfere with the oars. The progress of improvement, however, soon caused cannon to be mounted on their broadsides also, for which purpose spaces were left at certain intervals between the oars, the guns thus placed being fired over the gunwale, or, technically speaking, mounted *en barbet.*

About the latter end of the fifteenth century an alteration took place not only in the form of cannon but also in the manufacture of gunpowder, for it was soon observed that although the explosive properties of this composition were in every way so eminently calculated to supersede all other elastic forces employed in military projectiles, yet its application was extremely difficult on account of the great strength required in the cannon for resisting its violent reaction, and precluding the danger of bursting. Gunpowder, even in the earlier periods of its use, was capable of producing this difficulty, though so much inferior in strength to that of modern manufacture. It was also imagined that iron balls of much less weight than those of stone would be more effectual if impelled by greater quantities of stronger powder. This occasioned a corresponding alteration in the form of cannon, which were made lighter and more manageable than hitherto, although having a much greater quantity of metal in proportion to their bore or calibre. The balls were made of iron of from 40 to 60 lb. weight, being impelled with greater velocities, were capable of producing greater effects than the heaviest stone shot.

The cannon made by Charles VIII. of France were generally 50-pounders. Previously to this time the powder was always made in the mealed state, or as it was left by merely pounding or grinding the materials together, and consequently in a short time the mixture was decomposed and rendered inefficient in point of strength; but whether granulation was first introduced with the view of preserving the strength of gunpowder or for convenience is now doubtful. It is most probable that the facility which grained powder would give to the loading of small arms, suggested the idea, as in this state it was at first confined to their use, for mealed powder continued to be used for cannon for many years after granulation had been adopted. The superiority, however, of corned powder, in the retention of its strength, finally caused that which was in the mealed state to be entirely laid aside except for pyrotechnical purposes.

The following proportions have at various periods been adopted in its manufacture:—

Nitre.	Sulphur.	Charcoal.
4 parts.	1 part.	1 part.
48 „	7 „	8 „
18 „	2 „	3 „
6 „	1 „	1 „
3lb.	3oz.	9oz.
75 parts.	10 parts.	15 parts.

The first cast guns, as already noticed, were of brass, or, more properly speaking, gun metal; and it was only when cannon came into general use that it was found necessary to introduce guns cast of *iron*, in order to lessen the expense attending the manufacture of a numerous artillery composed wholly of brass. Cannon of brass in the reign of Henry VIII., A.D. 1535, Figs. 1 and 2, Plate II. (still, we believe, at the Royal Military Repository, Woolwich,) are respectively a view of the upper side of this piece and a section at the trunnions. It is formed, with the ex-

Plate.2.

Fig. 1.

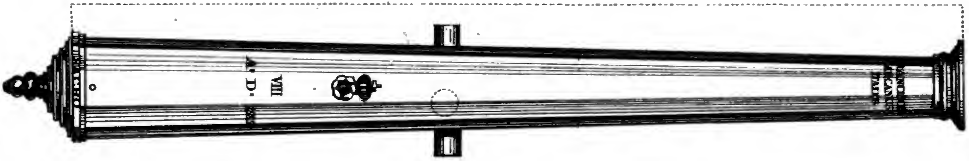


Fig. 2.

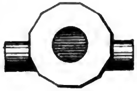
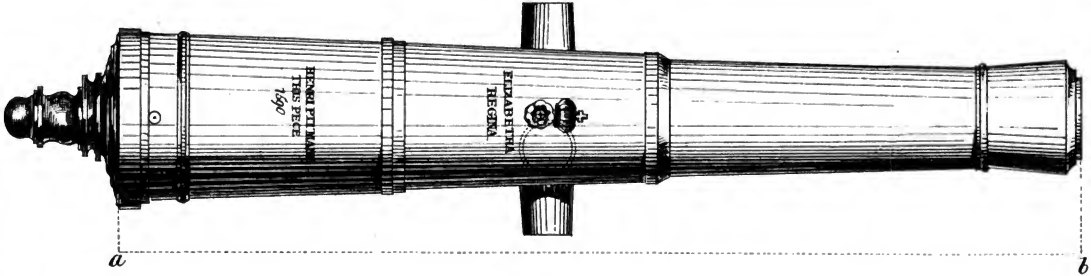


Fig. 3.



To face p. 231

ception of the cascable and rings near the muzzle, of the frustrum of a pyramid of twelve sides; its length from *a* to *b* is 7 feet 11 inches; it is remarkably elegant and simple in its appearance, and must have been regarded at the time of its manufacture as a fine specimen of the taste and ability of its founder, who seems to have been an Italian. The initials of Henry VIII., surmounted by a rose and a crown, the latter in relief, are perfectly preserved, as are also the name of the founder, Franciscus Arcanus, the date 1535, and the word "Sacro" cut on the base ring. The bore of this gun is 3·85 inches, which would take a ball of about 7lb. weight.

It was not until 1547 that cast-iron guns were made in England, in the reign of Edward VI., when a French gun-founder, who had previously been employed in the service of Henry VIII., cast some iron guns.

Elizabeth had many brass and iron guns cast about 1559, and Fig. 3, Plate II., is an exact representation of a brass Culverin or 18-pounder cast in 1590. Its length from *a* to *b* is 8 feet 6½ inches, and it has a bore of 5·45 inches in diameter. This gun has an iron vent, and from its length no doubt was a sea service gun; for in those days the cannon used on land were of such extravagant lengths as to preclude the possibility of using them on board ships. It therefore became necessary to manufacture pieces expressly for the sea service. The celebrated Culverin at Dover Castle, called Queen Elizabeth's Pocket Pistol, is 21 feet long. It was given by the Emperor Charles V. to Henry VIII.

It has been erroneously supposed that the manufacture of gunpowder did not take place in England until the reign of Elizabeth; but it was made in this country before 1552, if not in the beginning of the preceding century. It is true that Elizabeth had a great quantity made, and probably this has given rise to the conjecture that she first introduced its manufacture into her dominions.

At the battle of Lepanto in 1571 the Venetians introduced into their line a new and modified species of Galley, to which was given the name of Galleas. Several of these had 8 guns of large calibre, demi-cannon or 32-pounders at the head and stern, exclusive of those at the broadside between the oars, pointed through apertures cut in the gunwale, which was heightened for that purpose. The Spanish Armada in 1588 had four vessels of this description, carrying 50 guns each.

The names by which the various description of cannon were distinguished were of French invention. The following is a table of the description of ordnance used in England in 1599 :—

Name.	Bore.	Weight of Shot.	Name.	Bore.	Weight of Shot.
Cannon	8 in.	60 lb.	Falcon	2½ in.	2 lb.
Demi-Cannon...	6¾ ,,	33 ,,	Falconet	2 ,,	1½ ,,
Cannon Petro...	6 ,,	24 ,,	Minion	3½ ,,	4 ,,
Culverin	5½ ,,	18 ,,	Saker	3½ ,,	5 ,,
Demi-Culverin	4 ,,	9 ,,	Rubinet	1 ,,	½ ,,

But before this time it was customary to dignify cannon with uncommon names. Thus, Louis XII. in 1503 had twelve brass cannon cast of an extraordinary size, called after the twelve peers of France; the Spanish and Portuguese called theirs after their saints; the Emperor Charles V., when he marched against Tunis, founded the twelve Apostles; at Milan there was a 70-pounder called the Piedmontelle, and one at Bois-le-duc called the Devil; an 80-pounder in the Tower of London, brought from Edinburgh Castle, called Mount's Meg; an 80-pounder in the Royal Arsenal at Berlin called the Thunderer; an 80-pounder at Malaga called the Terrible; two curious 60-pounders in the Arsenal at Bremen called the Messenger of Bad News; and lastly, an uncommon 70-pounder in the Castle of St. Angelo at Rome, made of the nails that fastened the copper plates which covered the ancient Pantheon, with this inscription on it—"Ex clavis trabalibus Porticus Agrippæ."

From the year 1599 to 1856, we discover in England no great improvement in the manufacture of artillery; some interesting experiments, however, were made in 1775, an account of which was published in the "Philosophical Transactions," for 1778. The charges of powder were varied from 2 to 3 oz., and the shot from 1 to 3 lb. And from these experiments were deduced the following inferences:—

"1st. That gunpowder fires almost instantaneously.

"2nd. That the velocities communicated to balls or shot of the same weight, by different quantities of powder, are nearly in the subduplicate ratio of those quantities; a small variation, in defect, taking place when the quantities of powder became great.

"3rd. And when shot of different weights were employed, with the same quantity of powder, the velocities communicated to them are nearly in the reciprocal subduplicate ratio of their weights.

"4th. So that, universally, shot which are of different weights, and impelled by the gases of different quantities of powder, acquire velocities which are directly as the square roots of the quantities of powder, and inversely, as the square roots of the weights of the shot, nearly.

"5th. It would therefore be a great improvement in artillery, to make use of shot of a long form, or of heavier matter; for thus the momentum of a shot, when fired with the same weight of powder, would be increased in the ratio of the square root of the weight of the shot.

"6th. It would also be an improvement to diminish the windage; for by so doing, one third more of the quantity of powder might be saved.

"7th. When the improvements mentioned in the last two articles are considered as both taking place, it is evident that about one half the quantity of powder might be saved, which is a very considerable object. But, important as this saving may be, it seems to be still exceeded by that of the article of the guns; for thus a small gun may be made to have the effect and execution of another of twice or thrice its size of the present mode, by discharging a shot of twice or thrice the weight of its natural ball or round shot. And thus a small ship might discharge shot as heavy as those of the greatest now made use of.

"Finally, as the above experiments exhibit the regulations with regard to the weights of powder and balls, when fired from the same piece of ordnance, &c., so, by making similar experiments with a gun, varied in its length, by cutting off from it a certain part before each course of experiments, the effects and general rules for the different lengths of guns may be certainly determined by them. In short, the principles on which these experiments were made are so fruitful in consequences, that, in conjunction with the effects resulting from the resistance of the medium, they seem to be sufficient for answering all the inquiries of the speculative philosopher, as well as those of the practical artillerist."

Another very extensive course of experiments was carried on at Woolwich in the years 1783, 1784, and 1785, by order of the Duke of Richmond, Master-General of the Ordnance. The objects of this course were very numerous, but the principal of them were the following:—

"1st. The velocities with which balls are projected by equal charges of powder, from pieces of the same weight and calibre, but of different lengths.

"2nd. The velocities with different charges of powder, the weight and length of the gun being the same.

"3rd. The greatest velocity due to guns of different lengths, to be obtained by increasing the charge as far as the resistance of the piece is capable of sustaining.

"4th. The effect of varying the weight of the piece, everything else being the same.

"5th. The penetration of balls into blocks of wood.

"6th. The ranges and times of flights of balls, to compare them with their initial velocities, for determining the resistance of the medium.

"7th. The effect of wads; of different degrees of ramming; of different degrees of windage; of different positions of the vent; of chambers, and trunnions, and every other circumstance necessary to be known for the improvement of artillery."

In these experiments the balls were most of them of one weight; but the powder was increased from one ounce up till the bore was quite full. The conclusions from the whole were as follows:—

"1st. That the former law between the charge and velocity of ball was again confirmed, viz., that the velocity is directly as the square root of the weight of powder, as far as to about the charge of 8oz.: and so it would continue for all charges were the guns of an indefinite length. But, as the length of the charge is increased, and bears a more considerable proportion to the length of the bore, the velocity falls the shorter of that proportion.

"2nd. That the velocity of the ball increases with the charge to a certain point, which is peculiar to each gun, where it is greatest; and that by further increasing the charge the velocity gradually diminishes till the bore is quite full of powder. That this charge for the greatest velocity is greater as the gun is longer, but not, however, in so high a proportion as the length of the gun is; so that the part of the bore filled with powder bears a less proportion to the whole in the long guns than it does in the short ones; the part of the whole which is filled being, indeed, nearly in the reciprocal sub-duplicate ratio of the length of the empty part, and the other circumstances in the following table:—

Gun Number.	Length of the Bore.	Length filled.	Part of the Whole.	Weight of the Powder.
	inches.	inches.		oz.
1	28·5	8·2	$\frac{4}{12}$	12
2	38·4	9·5	$\frac{4}{16}$	14
3	57·7	10·7	$\frac{4}{22}$	16
4	80·2	12·1	$\frac{4}{27}$	18

"3rd. It appears that the velocity continually increases as the gun is longer, though the increase in velocity is but very small in respect of the increase in length, the velocities being in a ratio somewhat less than that of the square roots of the length of the bore, but somewhat greater than that of the cube roots of the length, and are, indeed, nearly in the middle of the ratio between the two.

"4th. The range increases in a much less ratio than the velocity, and, indeed, is nearly as the square root of the velocity, the gun and elevation being the same. And when this is compared with the property of the velocity and length of gun in the foregoing paragraph, we perceive that very little is gained in the range by a great increase in the length of the gun, the charge being the same. And, indeed, the range is nearly at the fifth root of the length of the bore, which is so small an increase as to amount only to about one-seventh part more range for a double length of gun.

"5th. It appears that the time of the ball's flight is nearly as the range, the gun and elevation being the same.

"6th. It appears also that there is no sensible difference caused in the velocity or range by varying the weight of the gun, nor by the use of wads, nor by different degrees of ramming, nor by firing the charge of powder in different parts of it.

"7th. But a great difference in the velocity arises from a small degree of windage. Indeed, with the usual established windage only—namely, about one-twentieth only of the calibre, no less than between one-third and one-fourth of the powder escapes and is lost; and, as the balls are often smaller than that size, it frequently happens that half the powder is lost by unnecessary windage.

"8th. It appears that the resisting force of wood to balls fired into it is not constant; and that the depths penetrated by different velocities or charges are nearly as the logarithms of the charges, instead of being as the charges themselves, or, which is the same thing, as the square of the velocity.

"9th. These, and most other experiments, show that balls are greatly deflected from the direction they are projected in, and that so much as 300 or 400 yards in a range of a mile, or almost one-fourth of the range, which is nearly a deflection of an angle of fifteen degrees.

"10th. Finally, these experiments furnish the following concomitant data, to a tolerable degree of accuracy—namely, the dimensions and elevation of the gun, the weight and dimensions of the powder and shot, with the range and time of flight, and the first velocity of the ball.

"'The following is a little table of experiments made with a 1-pounder gun and a two inches diameter iron shot, giving the ranges and time of flight:—

Powder.	Elevation of Gun.	Velocity of Ball.	Range.	Time of Flight.
oz.	°	feet.	feet.	″
2	15	860	4,100	9
4	15	1,230	5,100	12
8	15	1,640	6,000	14½
12	15	1,680	6,700	15½
2	45	860	5,100	21

"In the year 1824 Captain Norton completed an elongated rifle shot and shell, and in 1826 we find him using them at Dublin, Woolwich, Addiscombe, and Sandhurst, as well as at various other places, with complete success. In 1832 he is at Windsor firing a flat-fronted steel punch-formed rifle shot from an air-gun through a Life Guard's cuirass, and exploding powder placed on the other side. This steel punch-fronted rifle shot was tested at Woolwich in 1828, when he stated that it might also be converted into a shell by drilling a hollow tube into its front."

Again, in 1827 attention was attracted to this subject by the experiments of Major-General Ford, R.E., with an iron-plated target with granite backing; but the 24-pounder gun proved superior to it, and it was not until 1854 that attention was thoroughly roused to the subject of improved ordnance, when iron plates of 4½ inches, backed with 4 inches of fir, strongly bolted to a well-braced and strutted timber frame, were experimented with. Ten rounds were fired from a 32-pounder at 360 yards, all striking the plates. One shot produced an indentation of 2 inches. Two in nearly the same place produced an indentation of 2¼ inches, slightly cracking the plate besides, and four others cracked a plate in as many places, and bulged it 3½ inches. All the shot were broken up. Two 68-pounder shot, with 16lb. charges, produced 1½-inch indentations at 1250 yards. Ten of the same shot with 13lb. charges at 400 yards produced indentations of 2½ inches, and one of the same shot with a 16lb. charge at 400 yards shattered plates and backing; but it must be remembered that armour-plate manufacture was then in its infancy. In 1858 some experiments took place at Portsmouth to test the comparative effect of 68-pounders and 32-pounders at close quarters, and the penetrating power of shell, red-hot shot, and hollow shot also at close quarters. For the experiment 4-inch wrought-iron plates were attached to a ship's side, and it was then found that at 100 yards five 32-pounder shot striking close together did less execution on the armour, and much less on the woodwork of the ship than one 68lb. shot. It was also found that at 20 yards the 68-pounder cast-iron shot, with the ordinary 16lb. service charge of powder, did not penetrate the armour, while a 72-pounder wrought-iron shot with the same charge merely penetrated the plate. Shell, hollow shot, and red-hot shot made very little impression on the 4-inch plates at 400 or 200 yards, and cast-iron shot did very little more damage at 20 than at 100 yards.

The introduction of armour plating led to the improvement of ordnance, and, among others who have devoted their attention to the subject in England, Sir William Armstrong and Mr. Whitworth appear to have met with the greatest success. But the entire system of rifling ordnance, as at the present time in practice, appears likely to be superseded by Mr. Mackay's system, which appears to be more simple, cheaper, and more effectual. The ordinary system of rifling has been to obtain by mechanical means the rotation of the projectile, which is essential for accurate firing, *i.e.*, the explosive force of the powder has been exerted to force a screw projectile through a screwed tube, the screw projectile fitting the thread of the screwed or grooved tube of the gun on its passage out; much, therefore, of the explosive force of the powder is absorbed in overcoming the friction of the projectile. Moreover, the continual travelling by constant firing of the screw projectile over the screwed bore of the gun by mere direct pressure is destructive of the gun in destroying the screw threads and causing excessive strain on the gun itself. Mr. Mackay's system entirely does away with this mechanical screw, and he obtains the rotary motion of the projectile by the gas generated by the powder. The Mackay gun is grooved, but not for the purpose of the projectile travelling through it to obtain its rotary motion, but for the gases. The projectile is perfectly smooth and as nearly as practicable fits the smooth bore of the gun; the spiral grooves thus assist windage when ramming home the shot, the gas generated by the powder having a perfectly free access through these grooves in the bore of the gun. The projectile being perfectly smooth and not fitting into the grooves of the gun, allows the gas to pass through these grooves readily, and in advance of the projectile; having no obstruction and travelling faster than the projectile, gives it the necessary, and if we may judge by such experiments as have taken place, the most effectual, rotary motion. The direct tendency of the gas rotating around the projectile is to make the centre line of the projectile coincide with the centre line of the bore of the gun, and consequently the projectile would pass out without touching the bore of the gun; there is no wear and tear, therefore, of the gun by the projectile as in the ordinary system of rifling.

With the increased power of ordnance, increased weight has been a necessary consequence. The following table will show at a glance the power and weight of new ordnance as compared with the 68-pounder, which formerly was practically the largest gun in use:—

TABLE.

Gun.	Weight of Gun.	Rifling Turns.	Length of Bore.	Diameter of Bore.	Diameter of Shot.	Weight of Charge.	Estimated Weight of a Spherical Shot.	Character of Projectile.	Weight of Projectile.	Velocity.
RIFLES.	lbs.	Calibres.	Calibres.	in.	in.	lbs.	lbs.		lbs.	Feet per second.
Armstrong 600-pr.	51,296	1 in 65	—	13·3	—	70	330	—	601	—
Armstrong 300-pr.	26,880	”	11·81	10·5	—	75	162	Round end; zinc studs and ribs.	300	1715 initial.
”	”	”	”	”	—	45	”	”	301	1293·1 at 200 yds.
”	”	”	”	”	—	”	”	”	288	1318·4 at 200 yds.
”	”	”	”	”	10·337	”	”	Solid sphere	163	1627 at 508 ft.
”	”	”	”	”	—	”	”	Round end, hollow	230	1400·6 at 563 ft.
”	”	”	”	”	—	”	”	Round end, solid..	307	1228·4 at 563 ft.
Armstrong 150-pr.	14,896	—	19	7·52	7·50	40	60	Round end shot...	150	1770 initial. 1485 at 1,000 yds.
Whitworth 150-pr. 7-inch.	—	1 in 18·57	19·5	6·4 and 7	·06*	27	40	Flat fronted shot; no soft metal.	151	1170 at 780 yds.
”	—	”	”	”	”	25	”	”	150	1241 at 563 ft.
”	—	”	”	”	”	25	”	”	131·3	1268 at 780 yds.
”	—	”	”	”	”	27	”	”	130	1227 at 780 yds.
”	—	”	”	”	”	25	”	”	130	1268 at 580 yds.
”	—	”	”	”	”	27	”	”	129·5	1204 at 780 ft.
”	—	”	”	”	”	23	”	”	129	1278·5 at 580 yds.
Armstrong 110-pr.	9,184	1 in 37	14·2	7	No windage.	11	48	Round end shot; lead coating compressed.	174	892 initial; 890 at 30 yds.; 885 at 100; 887 at 200.
”	”	”	”	”	”	10	”	”	200	780 initial.

,,	9,184	,,	,,	,,	,,	12	,,	,,	150	995 initial; 992 at 30 yds.; 983 at 100; 974 at 200.
,,	,,	,,	,,	,,	,,	16	,,	,,	111	1307 initial; 1300 at 30 yds.; 1287 at 100; 1271 at 200.
,,	,,	,,	,,	,,	,,	14	,,	,,	111	1211 initial; 1205 at 30 yds.; 1193 at 100; 1178 at 200.
,,	,,	,,	,,	,,	,,	12	,,	,,	—	1125 initial; 1120 at 30 yds.; 1109 at 100; 1094 at 200; 980 at 1,000.
,,	,,	,,	,,	,,	,,	,,	,,	,,	103	1166 initial; 1160 at 30 yds.; 1149 at 100; 1133 at 200.
,,	,,	,,	,,	,,	,,	16	,,	,,	68	1433 initial.
,,	,,	,,	,,	,,	,,	18	,,	,,	60	1581 ,,
Parrott, 100-pr. ...	9,700	1 in 33·72	10·3	6·4	,,	10	37	Conical end shell; brass ring.	100	2154 ,,
,,	,,	,,	,,	,,	,,	10	,,	,,	80	1374 ,,
,,	,,	,,	,,	,,	,,	11	,,	,,	80	1405 ,,
,,	,,	,,	,,	,,	,,	10	,,	Spherical shot; paper sabot.	32	1829 ,,
Armstrong 70-pr. shunt.	9,016	1 in 45	14·8	6·4	6·25	11	,,	Round end shell.	74·6	1318·7 initial; 1311·7 at 90 ft.
,,	,,	,,	,,	,,	,,	10	,,	,,	74·4	1259 initial.

* Windage on half sides.

TABLE—(*continued.*)

Gun.	Weight of Gun.	Rifling Turns.	Length of Bore.	Diameter of Bore.	Diameter of Shot.	Weight of Charge.	Estimated Weight of a Spherical Shot.	Character of Projectile.	Weight of Projectile.	Velocity.
RIFLES.	lb.	Calibres.	Calibres.	in.	in.	lb.	lb.		lb.	Feet per second.
Whitworth 70-pr.	8,582	1 in 18·18	11·8	5 & 5·5	·035*	12	20	Flat fronted shell; no soft metal.	68·5	1275·8 initial.
„	„	„	„	„	„	13	„	„	81	1107 at 580 yds.
„	„	„	„	„	„	13	„	„	72·31	1148 at 580 yds.
Armstrong 40-pr.	3,986	1 in 36·5	17·2	4·75	No windage.	5	15	Round end; lead coating compressed.	41	1174·8 initial; 756 at 2,000 yds.
Parrott 30-pr......	3,550	1 in 34·04	28·5	4·2	„	3·75	10	Conical end shell; brass ring.	28	1215 initial.
„	„	„	„	„	„	4	„	„	„	1436 „
Armstrong 12-pr.	952	1 in 38	24·5	3	3·07†	1·5	4	Round end shell; lead compressed.	11·75	1238·7 „
„	—	„	„	„	3·01†	2·92	„	„	11·69	1740 „
Mackay 68-pr.	20,160	—	—	8·12	—	30	68	—	153	2200 spherical
SMOOTH BORES.										
Rodman, 15-in. Army.	—	—	11·	15·	14·74	50 cake	474	Spherical shell ...	330	1118 initial.
„	—	—	„	„	„	40	„	„	315	1250 initial; 1210 at 100 yds.; 1160 at 200; 1080 at 400; 890 at 1000.

U.S. Navy 15-in. gun.	4,200	—	8·66	15·	14·80	474	—	Spherical cored shot.	400	1480 initial.
Horsfall 13-in. gun	53,846	—	12·2	13·014	12·614	74·40	—	Spherical shot.....	279·50	1631 "
"	"	—	"	"	12·883	"	—	"	284·8	1299·2 at 800 yds.
Armstrong 150-pr.	—	—	11·9	10·48	10·41	40	—	"	150	1726 initial; 1710 at 30 yds.; 1645 at 100; 1586 at 200; 1168·3 at 1,000.
"	—	—	"	"	"	90	—	"	150	2010 initial.
U.S. 10-in. Columbiad.	15,059	—	10·55	10·	9·87	18	—	"	127	1315 initial; 1270 at 100 yds.; 1217 at 200; 1150 at 400; 957 at 1,000.
"	—	—	"	"	"	18	—	Spherical shell	101	1475 initial.
British 87 cwt. 10-in. gun.	—	—	10·9	10·	9·84	12	—	Spherical hollow shot.	88·31	1292 "
Armstrong 100-pr.	—	—	—	9·21	9·08	25	—	Spherical shot	113	1461·8 at 563 ft.
British 95 cwt. 68-pr.	—	—	14·	8·12	9·84	16	—	"	66·25	1292 initial.
"	—	—	"	"	"	16	—	"	66	1579 at 30 yds.
"	—	—	"	"	"	16	—	"	66	1488 at 100 yds.
"	—	—	"	"	"	16	—	"	66	1422 at 200 yds.
"	—	—	"	"	"	16	—	"	66	988 at 1,000 yds.
"	—	—	"	"	"	16	—	"	66	341 at 2,000 yds.
British 65 cwt. 8-in. gun.	—	—	13·	8·05	7·85	10	—	Spherical shell ...	46	1487 initial.
U.S. 8-in. Columbiad.	8,465	—	11·	8·00	7·88	10	—	Spherical shot.....	65	1375 "
"	—	—	"	"	"	10	—	Spherical shell ...	50	1570 "

Windage on half sides.

† No windage.

BROADSIDES.

The first introduction of cannon into naval warfare, as before remarked, was in 1372 by the Spaniards; they were mounted at the two extremities of the galleys, so as to fire over the bow and stern in a fore and aft direction,* and soon after over the gunwale and, as ships increased in size, holes through the sides of the ship were made, termed broadside ports, as distinguished from the bow ports and stern ports. Descharge, a French builder at Brest, is said to have been the inventor of portholes, and they were used in England in the early part of the 16th century.

It is reported that at the battle of Lepanto, which was fought on the 7th October, 1571, some of the galleons carried demi-cannon nearly equal to our 32-pounders, and in 1588 there were four of these vessels in the Spanish service, each of which is said to have carried 50 guns; they retained in their ships at the time of the Armada much of the peculiarity of the galley. At the commencement of the 16th century our permanent naval force consisted of only 57 vessels, each carrying 21 men and a boy. Fifty years later it consisted of only 21 ships and vessels of the total burthen of 4,380 tons, carrying 302 arquebusses, 568 soldiers, 324 gunners, and 1,988 mariners. On the accession of Elizabeth a new era was inaugurated. She ordered a special survey of the navy to be made and an inquiry into its recent decay. Ships of various dimensions were built and large quantities of arms were imported from Germany, and from the encouragement she gave to shipping she was called by foreigners "The Restorer of the Glory of Shipping and the Queen of the North Sea;" and in the fleet sent against the Spanish Armada there were 18 new ships, the largest was of 800 tons, one of 600 tons, three of 500 tons, and the remainder of less burthen.

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* This system has recently been sought to be revived by Mr. McLane, who styles it the "End on" system. Gunboats invariably fight their heavy guns at the bow or stern, and thus present the lesser target to their antagonist.

The Spanish Armada consisted of 133 ships, making in all 57,868 tons, on board of which were 19,295 soldiers, 8,450 marines, 2,088 slaves, and 2,630 pieces of cannon.

The navy of England consisted of 34 vessels, all of which, except two, were under 1,000 tons burthen; the burthen of these amounted to 11,850 tons. These, however, were assisted by the merchant navy, consisting of 163 vessels; of these 83 were from 400 to 100 tons burthen, 58 of from 90 to 30 tons burthen, and the remainder of less burthen.

The progressive increase of the Royal Navy, by which it has arrived at its present state, has, in fact, been almost continuous from the time when it became a national establishment, in the reign of Henry VIII. At his death it amounted to 12,455 tons; during the reign of Edward VI. it declined to 11,065 tons; at the death of Queen Mary it was only 7,110 tons; in the reign of Elizabeth it increased to about 17,110 tons; but by 1618 it had diminished to 16,040 tons, and of this rather more than one-fourth was deemed unserviceable. At the beginning of the civil war it was 22,400 tons; at the Restoration it was 57,463 tons. In the reign of Charles II. it rose to 103,558 tons, but at the abdication of James II. it was only 101,892 tons. At the death of William III.

it was 159,020 tons; at the death of Queen Anne it was 167,219 tons; at the death of George I. it was 170,862 tons; at the death of George II. it was 321,104 tons. In the year 1806 it was 776,057 tons, and in 1810 the fiftieth year of the reign of George III. it was 800,000 tons. At the death of George IV. it was 554,846 tons, at the death of William IV., in 1837, it was 536,033 tons. In 1847, including steam vessels, it was 645,550 tons.

The following table shows the number of screw and sailing vessels of the Royal Navy afloat at the commencement of the present year, in addition to the iron-clads given in the table on page 252A:—

Classes of Ships.		Steam Vessels Afloat.	Effective Sailing Ships Afloat.
Ships of the Line	Screw	55	1
Frigates	,,	37	9
,, ...	Paddle	6	—
Block Ships	Screw	8	—
Corvettes	,,	26	—
Sloops	,,	35	4
,, ...	Paddle	19	—
Small Vessels	,,	13	—
Despatch Vessels	,,	4	—
Gun Vessels	Screw	37	—
Gun Boats	,,	105	—
Tenders, Tugs, &c.	,,	7	1
,, ...	Paddle	40	—
Mortar Ships	Screw	4	—
Troop and Store Ships	,,	15	—
,, ...	Paddle	1	—
Yachts	Screw	1	—
,, ...	Paddle	5	—
Mortar Floats	——	—	54
Total Screw...............		330	—
Total Paddle		88	—
Grand Total		418	69

The first line-of-battle ship with three fighting decks appears to have been the "Royal Sovereign," built by Mr. Phineas Pett; her keel was laid at Woolwich Dockyard, on the 21st December, 1635, and she was launched in October, 1637. The following is the description given of her by Thomas Heywood:—

Her greatest length was	232	feet
Length of keel	128	,,
Main breadth	48	,,

"Shee hath three flush deckes and a forecastle, an halfe decke, a quarter decke, and a round house. Her lower tyre hath thirty ports, which are to be furnished with demi-cannon and whole cannon throughout, being able to beare them; her middle tyre hath also thirty ports, for demi-Culverin; her third tyre hath twentie-sixe ports for other ordnance; her forecastle hath twelve, and her half decke hath fourteene ports; she hath thirteene or fourteene ports more within board for murdering pieces, besides a great many loop-holes out of the cabins for musket-shot. Shee carrieth, moreover, ten pieces of chase ordnance in her right forward, and ten right aff, according to land service, in the front and the reare." She was accidentally burnt at Chatham, on the 27th January, 1696.

The following table exhibits the establishment of the different classes of vessels in the Royal Navy, with their armaments, before the introduction of the screw propeller into the navy:—

TABLE.

	1st Rate.			2nd.			3rd.			4th.		
	Ft. in.			Ft. in.			Ft. in.			Ft. in.		
Length on the Gun-deck...	205 0			196 5½			175 9			176 0		
„ of Keel for Tonnage	170 7			162 3½			144 6⅞			144 6½		
Breadth extreme	53 4			51 5½			47 8			52 8½		
Depth in Hold	24 0			22 6			21 0½			17 1		
Tonnage.....................	2,609 Tons.			2,284 Tons.			1,740 Tons.			2,082 Tons.		
Complement of Men and Officers	1,000			750			650			500		
No. of Guns	120			84			72 to 76			50		
	No. of Guns.	Weight of each.	Length.	No. of Guns.	Weight of each.	Length.	No. of Guns.	Weight of each.	Length.	No. of Guns.	Weight of each.	Length.
		cwt.	′ ″		cwt.	′ ″		cwt.	′ ″		cwt.	′ ″
Lower Deck	32 { 4 of 8 in. 28 32-pdrs.	65 56	9 0 9 6	30 { 6 of 8 in. 24 32-pdrs.	65 56	9 0 9 6	28 { 4 of 8 in. 24 32-pdrs.	65 56	9 0 9 6			
Middle Deck	34 { 2 of 8 in. 32 32-pdrs.	65 50	9 0 9 0									
Main Deck..................	34 32-pdrs.	41	8 0	32 { 2 of 8 in. 30 32-pdrs.	65 48	9 0 8 0	28 32-pdrs.	41	8 0	28 { 6 of 8 in. 22 32-pdrs.	65 56	9 0 9 6
Quarter Deck and Fore-castle	20 { 6 32-pdrs. 14 32-pdr. Carronades.	45 17	8 6	22 { 6 32-pdrs. 16 32-pdr. Carronades.	41 17	8 0	16 { 4 32-pdrs. 12 32-pdr. Carronades.	41 17	8 0	22 32-pdrs.	45	8 6
Total Weight of the Guns.	273 Tons.			203 Tons.			156 Tons.			130 Tons 12 cwt.		
Weight of the Broadside in pounds	2,028			1,488			1,224			908		

TABLE.—*(continued.)*

	5th Rate.			6th.			Sloop rigged as ship.		
	Ft. in.			Ft. in.			Ft. in.		
Length on the Gun-deck	151 9½			130 0			113 3		
” of Keel for Tonnage	127 0⅞			105 9			92 10¼		
Breadth extreme	40 0⅝			40 7½			30 7		
Depth in Hold	12 9			11 6			8 0		
Tonnage	1,084 Tons.			913 Tons.			462 Tons.		
Complement of Men and Officers	320			240			130		
No. of Guns	42			26			18		
	No. of Guns.	Weight of each.	Length.	No. of Guns.	Weight of each.	Length.	No. of Guns.	Weight of each.	Length.
		cwt.	′ ″		cwt.	′ ″		cwt.	′ ″
Lower Deck									
Middle Deck									
Main Deck	28 { 2 of 8 in. 26 32-pdrs.	50 39	7 0 7 6	18 { 2 of 8 in. 16 32-pdrs.	50 40	7 0 7 6	18 { 2 32-pdrs. 16 32-pdrs.	25 17	6 0
Quarter Deck and Forecastle	14 { 4 32-pdrs. 10 32-pdr. Carronades.	39 17	7 6	8 { 2 32-pdrs. 6 32-pdrs.	40 25	7 6 6 0			
Total Weight of the Guns	72 Tons.			48 Tons 10 cwt.			16 Tons 2 cwt.		
Weight of the Broadside in pounds	708			452			288		

Since the introduction of the screw propeller other dimensions were found necessary, and more recently of armour-plating, and of the "central system" of armament of Captain Cowper Coles, no systematic scale or establishment for war vessels has yet been made. This is, doubtless, a very necessary point to be arrived at, as in squadrons of evolution, and in forming line of battle, we think there should be certain classes of vessels of certain definite armament, with a certain uniform speed of sailing and steaming. Then again there should be vessels of the greatest possible speed, with a limited number of the most powerful ordnance, which would perform, if we may be allowed the term, the "Light Cavalry" services for the fleet of line-of-battle ships.

The question as to armour-plating, its thickness and extent, is still an open one. We believe the guns will settle the question of the two systems of armament, whether the ancient system of broadside and bow and stern ports, or the modern central system of Captain Coles. For line-of-battle ships, perhaps, complete armour will be found the best, and partial armour, proof against the service 68-pounder, merely for fast and powerful *cruisers*, thereby admitting of a vessel being constructed of the most advantageous proportions for seaworthiness and speed, and yet not liable to be sunk by gun-boats or any number of vessels carrying ordnance of and under the service 68-pounder; entirely unprotected vessels, even of the maximum speed and carrying the heaviest ordnance, might otherwise be destroyed and sunk, but a fleet, or even a single gun-boat, armed with the service 68-pounder or ordnance of even less calibre.

The following table shows the number and power of our iron-clad fleet afloat up to June, 1865:—

Names.	Hull, hether of wood or Iron.	Whether wholly Armour Clad, or partially.
Black Prince	Iron.	Partially.
Warrior	Ditto.	Ditto.
Defence	Ditto.	Ditto.
Resistance	Ditto.	Ditto.
Achilles	Ditto.	Ditto.
Hector	Ditto.	Ditto.
Valiant	Ditto.	Ditto.
Minotaur	Ditto.	Wholly.
Agincourt	Ditto.	Ditto.
Royal Oak	Wood.	Ditto.
Prince Consort	Ditto.	Ditto.
Caledonia	Ditto.	Ditto.
Ocean	Ditto.	Ditto.
Royal Alfred	Ditto.	Partially.
Zealous	Ditto.	Ditto.
Bellerophon	Iron.	Ditto.
Lord Clyde	Wood.	Wholly.
Lord Warden	Ditto.	Ditto.
Pallas	Ditto.	Partially.
Favorite	Ditto.	Ditto.
Research	Ditto.	Ditto.
Enterprise	Ditto.	Ditto.
Royal Sovereign	Ditto.	Wholly.
Prince Albert	Iron.	Ditto.
Scorpion	Ditto.	Ditto.
Wivern	Ditto.	Ditto.
FLOATING BATTERIES.		
Erebus	Iron.	Wholly.
Terror	Ditto.	Ditto.
Thunderbolt	Ditto.	Ditto.
Etna	Wood.	Ditto.
Thunder	Ditto.	Ditto.

TURRETS.

In art or war that invention or discovery is generally of more certain utility and adaptability which is the offspring of the experience of necessity. Circumstances alone compelled the Anglo-Saxon of America to become an inventor; being placed in a position of not having the means which the Old World readily afforded him at hand, he was thus left almost entirely to the fertile resources of that wonder of all wonders the human brain, but which, unguided by experience, makes often ingenious but impracticable discoveries.

The turret or central system of Captain Cowper P. Coles, R.N., we may justly consider as the offspring of the Russian war of 1855, and of the experience of necessity; coming from such a source and from one who played his part in the actual operations as commander of the *Stromboli* against the Russian stronghold in the Black Sea, this invention or improvement in the art of war should have commanded greater consideration than if from a mere theorist. Captain Coles was in the fight, and in the fight the novel system of armament suggested itself to him. So greatly was his system of mounting guns approved of by the officers of the Black Sea fleet, that Captain Coles was detached from the fleet in order that he might proceed to London and lay before the Admiralty the invention which had suggested itself to him in actual warfare, recommended by those whose profession it is to work and fight guns at sea, and who it is but reasonable to suppose are or ought to be the best judges as to the best and most efficient system.

There are other questions and subjects doubtless in the construction of a ship on which the naval officer would not be the most competent authority, but the workman certainly is the best judge of the instrument he has to work with, although he may not be competent to make the instrument.

Captain Coles having laid his plans before the Admiralty, the trustees of the nation's navy, nothing more, it might naturally be supposed, was required from him. The Admiralty would doubtless examine this invention of a naval officer and either adopt or condemn it; but we cannot say they have actually done either, and now, after just ten years' experience, they are still *endeavouring to adopt*, but practically condemn it, and doubtless would have condemned it long since had not Captain Coles, with the true British sailor's determination, "stuck to his gun" to conquer or be conquered; but ten years is a long period, and the Admiralty still "stick" to the old system of broadside armament and ports; but it is perhaps, as one of the members of the Board of Admiralty stated a short time since, that "new systems require new men to carry them into practice," and like the reply of another ancient dignitary to inconvenient modern inventions, they answer "Non possumus" to all improvements not in accordance with their own preconceived notions. Ancient individuals as well as ancient systems are difficult to convince and break through even with facts staring them in the face. The Turret system has now been ten years under the consideration of the Admiralty; various experiments have been made,—the first by fitting a turret in the floating battery *Trusty*, which was tried under all circumstances, both as to its offensive and defensive power. These experiments were made in the year 1861, and proved in all points satisfactory. In the following year, 1862, the *Royal Sovereign*, a screw line-of-battle ship of three decks, and mounting 120 guns, was cut down and converted into a turret ship, and the *Prince Albert* ordered to be built, both being intended for mere "block ships," and not line-of-battle ships or cruisers, but for harbour defence only; no exception can be taken to these vessels, they are the most effective for the purpose they were designed, but from that time, 1862, nothing has been done to test the system in sea-going vessels, absolutely nothing so far as the Admiralty are concerned; on the contrary, they have evidently endeavoured to prevent its introduction into the fleets of England.

By the Americans in the late war the Turret system was successfully adopted, although in a very imperfect manner; yet notwithstanding the imperfect and faulty construction of their vessels, they proved the advantage of the central system of armament as compared with the broadside system.

The Russians have turret ships, the Prussians have turret ships, the Danes have turret ships, the Italians have a turret ship of great speed, and carrying heavy guns. In the Royal Navy there are only the two block ships on the turret principle, the *Royal Sovereign* and *Prince Albert*, and recently the *Wyvern* and *Scorpion*, designed and built for a special service, by a private shipbuilder, for a foreign Government.

We really thought the Admiralty were in earnest, and that they really meant to build a sea-going ship on Captain Cole's system of armament, when in March last the Secretary of the Admiralty called the attention of the House to "Vote 10." "They will see there (said he) a sum of £120,000 to be taken this year, being part of a whole sum of £240,000 for ships to be built by contract; this sum we propose to apply to the construction of one or more ships. The first proposal we have to make is that, if possible, *we should endeavour to construct a ship on Captain Coles's turret principle, which shall be a real sea-going vessel.* We have never yet succeeded in getting one of these vessels which, in the opinion either of Captain Coles himself or of other practical men, can be deemed a thorough sea-going ship. I have no doubt Captain Coles will have considerable difficulties to overcome in constructing a thorough sea-going ship on the turret principle.

* * * * *

Every one knows that a thorough sea-going ship must have masts and rigging, &c.," and then goes on to say, "Captain Coles has been directed by the Admiralty to prepare drawings, and has had the assistance of a draughtsman from the Admiralty."

Then in a debate on the Navy Estimates, a few days after making the foregoing statement, he says, "Now he had been asked why the Admiralty did not give him (Captain Coles) the construction of a sea-going ship? He was bound to say Captain Coles, though a very clever man, and understood the construction of the cupola, was not a shipbuilder nor a designer, and when he made his design in the year 1862, it was found that he had not calculated sufficient floatation for the weight, and therefore the design was not approved of," &c. We understand some of the vessels built under the auspices of Lord Clarence Paget have been wanting in sufficient floatation, and we are at a loss to understand these statements of Lord Clarence Paget's to the House. First he asks the House to vote a sum of money for a vessel which they (the Admiralty) should endeavour to construct, although "they had never yet been able" to do so, even after ten years' consideration of the subject. He then says "he has no doubt that Captain Coles will have considerable difficulty to overcome in constructing a thorough sea-going ship on the turret principle," but sends him a draughtsman from the Admiralty to prepare drawings, and then, a few days after, tells the House that "the reason why they do not give Captain Coles the construction of such a ship is that Captain Coles is neither a shipbuilder nor designer."

Captain Coles, however (although neither a shipbuilder nor designer), sent to the Admiralty a drawing prepared by an Admiralty draughtsman for a sea-going turret ship in April, 1865, which was referred to a committee. Their report on the advantages of the turret system appeared in our last number, Art. 12, but we think the design which no doubt the Admiralty had prepared also in accordance with Lord Clarence Paget's declaration to the House should have been submitted with Captain Coles's design to the same committee. Why this was not done we can't say, or whether they did or did not succeed "in endeavouring to construct a ship upon Captain Coles's principle." All we can say is that the money was voted by Parliament, but the Admiralty, after ten years' experience and trials, are still unable to construct a sea-going ship on Captain Coles's principle.

The Admiralty endeavour to maintain and uphold the mystery which in the olden times surrounded the construction and building of ships of war; they are ready to admit that merchant vessels may be constructed and built without their talents, but a vessel to carry guns and armour-plates is altogether another matter, a mystery only understood by the Admiralty; but unless the Admiralty ignore the laws of science in the construction of their vessels, and have some mysterious method, unknown to science, we cannot but believe that the laws of science which apply to merchant vessels are equally applicable to vessels of war; doubtless a vessel of war is a more intricate problem, and demands greater knowledge and experience. But we must look for reasons why the central system of Captain Coles has not been adopted, to other than either scientific or practical ones,—either in naval architecture, nautical science, or practical shipbuilding.

The advantages of a turret ship, in addition to those enumerated by the committee and Admiral Goldsborough (see Part 14, Article 12), are that a most efficient sea-going ship can be constructed to carry the most effective and powerful ordnance of less tonnage than would be required for a similarly effective vessel on the ancient broadside system, and thus we might maintain the effective power of broadside, of our fleets by smaller and more efficient vessels, and a consequent saving of public money by less tonnage and fewer number of sailors; or, on the other hand, with our same annual expenditure and with the same tonnage we might have a fleet of nearly double its present effective power.

In actual warfare the Turret system has a great advantage over the broadside system: the port of the turret can be turned completely away from the enemy in a quarter of a minute, whereas the broadside port is continually exposed. In the attack on Kinburn by the French floating batteries the only casualty was caused by a shot entering the port; and more recently in the American war, a Confederate armour-clad, proof against the Federal's projectiles, was prevented from firing her own guns by small shot fired by the Federal ship into the port-holes of the Confederate ship. The advantage, therefore, of turning the port away from the enemy cannot be overrated. Moreover, the area of weakness and opening is infinitely greater in the broadside than in the turret, as the following Table and Plate No. IV. will show:—

AREA OF BROADSIDE PORT-HOLE.

Outside Area.

Admitting of 8° elevation 2′ 9″ × 3′ 2″ = 8·709 sq. feet.
„ 12° „ 2′ 9″ × 3′ 7½″ = 9·968 „
„ 18° „ 2′ 9″ × 4′ 3½″ = 11·801 „

Inside Area, or Area of True Weakness.

Admitting of 8° elevation 6′ 8″ × 3′ 2″ = 21·111 sq. feet.
„ 12° „ 6′ 8″ × 3′ 7½″ = 24·166 „
„ 18° „ 6′ 8″ × 4′ 3½″ = 28·611 „

AREA OF TURRET PORT-HOLE.

Admitting of 18° elevation 1′ 10″ × 2′ 11″ = 4·625 sq. feet.

ART. XXII.—*Calculations made on Twenty Ships of the British Navy, with Observations respecting the Forms of some of those Ships.* By WM. HENWOOD, Naval Architect, Member of the late School of Naval Architecture. (Being a reprint from the *United Service Journal* for 1835, and in continuation of the Art. 13, Part 14, Vol. 4 of this series.)

THE following calculations have been made by the writer with the view of ascertaining how far the forms of the several classes of ships of the Royal

Navy differ from that form which ships of similar size would have, if they were to be constructed according to the principles advanced in Art. 13, Part 14 of "Papers on Naval Architecture," in "Inquiry respecting the means of reducing the motions of pitching and 'scending to a minimum."

It will be proper just to state that the principles referred to rest on the following considerations—namely, that when a ship is sailing, the pitching and 'scending motions always diminish the velocity of the vessel; and in a degree corresponding with the greatre or less degree of force with which those motions are performed. The motion of rolling can have very little effect in retarding the velocity of sailing, compared with the effect produced by the pitching. And it is accordingly obvious that if a ship can be so constructed and equipped that the force of the pitching and 'scending motions shall be made the least possible degree, whilst at the same time, the ship being rendered perfectly easy in her longitudinal motions when under sail, her hull, masts, and rigging would be subjected to only the least possible degree of straining. It will appear evident to every attentive reader of the paper above referred to, that a ship may be so constructed and equipped.

The forces with which a ship will pitch and 'scend depend (as was explained in Art. 13, Part 14 of this work) on the products of the displaced volumes of the fore and after bodies, and the squares of the distances of the centres of gravity of these bodies respectively from the common centre of gravity of the ship; and on the products of the weights before and abaft the centre of gravity of the ship and the squares of the distances of the common centres of gravity of those weights respectively from the same centre of gravity, or axis of the ship. As, however, the moments of the weights on each side of the axis are equal to each other, and the moments of the fore and after bodies likewise equal, it is sufficient, in comparing the force of pitching with the force of 'scending, to compare merely the distances of the centres of gravity from the axis in each case.

The accompanying table of calculations shows the force which the buoyancy of the water exerts on the fore and after bodies of the several ships, in producing their motion of pitching and 'scending. The tendency to pitch is represented by the distance of the centre of gravity of the after body from that of the ship; and the tendency to 'scend is in like manner expressed by the distance of the centre of gravity of the fore body from the same point. In the *Caledonia*, for example, the effect of the action of the water on the after body in making the ship pitch is expressed by $41\frac{85}{100}$, and the counteracting effect causing her to 'scend by $41\frac{39}{100}$. According to the principle I have endeavoured to establish in the above-mentioned paper, these effects of the buoyant force of the water on the fore and after bodies ought always, as they might, be made precisely equal to each other, whilst, at the same time, the weights which compose the ship on each side of the vertical plane passing through the transverse axis should not only be equal, but disposed of in such a manner that the common centres of gravity of those weights may be equally distant from the centre of gravity or tranverse axis of the ship.

TABLE of CALCULATIONS made on TWENTY SHIPS of the BRITISH NAVY.

—	Caledonia, 120 guns.	Rodney, 92 guns.	Royal Frederick, 110 guns.	Vengeance, 84 guns.	Vengeance,* 84 guns.	Vindictive, 74 guns.	Winchester, 52 guns.	President,* 52 guns.	Seringapatam, 46 guns.	Inconstant, 36 guns.	Minerva, 46 guns.
	ft. in.	ft. in.	ft. in.	ft. in	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Length at load water-line	205 0	204 0	202 5	194 2	194 11½	176 3	172 7	172 10	159 4	160 0	152 9
Breadth, extreme, at ditto	54 4½	54 4¾	59 8½	52 2½	52 2½	48 0	44 3	44 11	41 0	45 0	40 1¼
Depth from ditto to lower edge of keel-rabbet	feet. 21·82	21·27	22·91	20·655	21·825	20·25	19·1	18·5	16·05	18	16·32
Draught of water { Forward	ft. in. 23 7½	23 0	22 5¼	21 7½	22 1	21 3	20 1	19 1	16 8¼	19 5	17 6
Draught of water { Aft	24 7¼	24 1½	23 5¼	23 1½	24 10	22 7	21 2	21 8	18 2½	19 5	18 6
Displacement, in tons	4340	4165¾	4482¾	3387	3680	2903	2279	2123½	1531	1862	1428
Centre of gravity of ditto before middle of load water-line	feet. 1·463	2·445	1·843	3·672	2·467	1·972	1·662	4·397	2·84	2·79	2·38
Displacement before centre of gravity ...... cub. ft.	76364	73550	79320	59856	64836	51368	40180	38059	27226	32975	26381
Ditto abaft ditto ...... "	75530	72250	77574	58702	63974	50234	39602	36262	26366	32192	23949
Difference of fore and after-bodies, in tons	$23\frac{8}{10}$	$37\frac{1}{7}$	$49\frac{9}{10}$	33	$24\frac{8}{10}$	$32\frac{2}{5}$	16½	$51\frac{4}{10}$	$24\frac{6}{10}$	$22\frac{4}{10}$	$69\frac{4}{10}$
Distance of centre of gravity of fore-body from centre of gravity of displacement	feet. 41·89	40·99	40·51	37·09	37·74	34·96	33·54	32·95	31·56	30·74	25·103
Distance of ditto of after-body from ditto	41·85	41·72	41·42	37·82	38·25	35·75	34·03	34·58	32·58	31·49	27·688

* The calculations in the columns thus marked have been made at the sea-going draught of water, the others at the load water-line prescribed by their constructors.

TABLE of CALCULATIONS made on TWENTY SHIPS of the BRITISH NAVY—(*continued*).

—	Sapphire, 28 guns.	Imogene, 28 guns.	Challenger, 28 guns.	Rover, 18 guns.	Orestes, 18 guns.	Champion, 18 guns.	Columbine, 18 guns.	Scylla, 18 guns.	Waterwitch,* 10 guns.	Britomart, 10 guns.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Length at load water-line	120 0	126 0	126 11	109 9	111 2	110 10	102 7	97 6	88 11	86 9
Breadth, extreme, at ditto	34 0	33 10	32 8½	34 0	31 0	31 1	33 2¼	30 0	28 9½	24 7
	feet.									
Depth from ditto to lower edge of keel-rabbet	13·42	14·42	15·1	13·05	12·87	12·92	13·4	11·33	11·142	9·81
	ft. in.									
Draght of water { Forward	14 1¼	15 6	16 7	13 11⅓	13 10	14 6	14 4¼	10 7	10 2	10 7¾
Draght of water { Aft	15 5¼	16 4	16 7	14 11½	14 7	14 6	10 10¾	14 3	14 6	12 3¾
Displacement, in tons	770	873	943	563	606	615·8	524·8	421·8	330·8	278
	feet.									
Centre of gravity of ditto before middle of load water-line	1·76	2·17	2·35	2·253	2·415	1·226	4·25	1·312	·167	·517
Displacement before centre of gravity ...... cub. ft.	13636	15517	16730	10017	10805	10824	9435	7526	5804	4920
Ditto abaft ditto ...... „	13330	15052	16288	9722	10403	10732	8933	7239	5774	4808
Difference of fore and after-bodies, in tons	$8\frac{6}{10}$	$13\frac{9}{10}$	$12\frac{6}{10}$	$8\frac{4}{10}$	11⅓	2⅔	$14\frac{3}{10}$	$8\frac{2}{10}$	$\frac{86}{100}$	$3\frac{5}{10}$
	feet.									
Distance of centre of gravity of fore-body from centre of gravity of displacement	23·22	24·78	24·76	20·74	21·63	21·94	18·79	17·91	16·44	16·66
Distance of ditto of after-body from ditto	23·75	25·54	25·43	21·37	22·46	22·12	19·84	18·88	16·52	17·05

* The calculations in the column thus marked have been made at the sea-going draught of water, the others at the load water-line prescribed by their constructors.

The *Caledonia* has been considered by many distinguished naval officers as a ship possessing good if not superior sailing qualities. And in making a comparison between this well-known ship and the ships of three decks in the foregoing table, it will be seen that the form of her bottom is such that her tendency to pitch is more nearly equal to her tendency to 'scend than the same elements of either the *Rodney* or the *Royal Frederick.* If the latter ships should be stowed with reference to the position of their centres of gravity of displacement in the same manner as the *Caledonia* has been, they will most certainly pitch with greater force than that ship, and the *Royal Frederick* will be the most laboursome ship of the three.

The situations of the centres of gravity of these ships with respect to the middle point of the load water-line are so far different, that it must be supposed that all of them are not equally good. It appears exceedingly desirable that a Naval Architect, before beginning to construct a vessel of such magnitude and value, should be able to ascertain the best position for placing this highly important point, through which the axis of rotation pass, and upon which the excellence of a ship essentially depends. If the axis of rotation is too far aft, it is plain that the ship will pitch too heavily; and if the axis is placed too far forward, the 'scending will be excessive; and in either case the sailing must be retarded. It evidently appears there is a mean position where the centre of gravity of a ship ought to be placed, in order that her sailing may be impeded by the impact of the ship and the water in pitching in the least possible degree; and this desirable point can be determined without any considerable difficulty.

The difference in the situations of the centres of gravity of these ships will, in a slight degree, modify the numbers which have been found as expressions of the forces of pitching and 'scending. The centres of gravity in the *Royal Frederick* being about four inches further forward than in the *Caledonia*, will, provided both ships are stowed in the way above supposed, diminish in a small degree, the comparatively great difference of the tendencies to pitch and 'scend in the *Royal Frederick*. And the position of the centre of gravity in the *Rodney* will modify the numbers which represent the forces of the water acting on her in a similar manner.

In adverting to the two calculations made on the *Vengeance*, it is deserving of notice that this ship exhibits in a striking point of view how desirable it is that the construction of our ships of war should be conducted on other principles than those which have served as the guide of Naval Architects. This ship was constructed to sail only eighteen inches by the stern, and her decks were placed with their fore and after ends about fifteen or sixteen inches higher than the midship part. The necessity of bringing this ship not less than fifteen inches more by the stern than her constructor designed her to be, in order to make her sail well, makes the lowest part of her decks to be very near the stern instead of in midships, so that the water on her decks must run aft against her cabins and less readily find a passage out of the ship. But this is not all. The appearance of the ship, as she floats on the water, is altogether spoiled, and an impression is made on the mind of every reflecting beholder, that her constructor could not have known the way to make such a ship as he desired.

A very erroneous notion has been entertained by some persons that it is the part of those who have to navigate a ship to find out her trim, or best sailing draught of water. And this opinion appears to have been held quite as tenaciously by naval constructors as by other persons. Nothing but a very imperfect acquaintance with the science of Naval Architecture could have admitted the formation of such an opinion. A very little reflection will suffice to satisfy every well-informed individual that the Naval Architect who merely delineates the form of the hull of a ship, and allows the weights to be stowed in her according to the discretion or caprice of another person, fulfils but half the duty of his office. He leaves the completion of his work, which is all but the most important part of it, to be executed by those who it must be presumed are uninformed of the proper mode of doing it, and it would be but fair to consider a ship built and equipped in this manner as the joint production of her Architect and those who equip her for service.

If the constructor of the draught from which the *Vengeance* was built had been required to arrange all the weights on board his ship preparatory to her going to sea, he would, it is to be supposed, in conformity with his design, have brought her to swim only eighteen inches by the stern. The ship when at sea would, in all probability, or rather of necessity, have been found to plunge violently and deep in the act of pitching, and it would have been found expedient to break up the hold and re-stow the ship in order to prevent her from carrying away her mast and rigging. This class of ship appears to have been found by various officers who have had the command of them to sail best at the draught of water in the second calculation, or even somewhat more by the stern. At this draught of water the tendency to pitch arising from the effect of the fluid on the bottom is much more nearly equal to the tendency to 'scend than when the ship is only eighteen inches by the stern. And as the altered stowage by which the difference in the draughts of water forward and aft was increased from one foot six inches to two feet nine inches, must also have rendered the force of pitching much more nearly equal to the force of 'scending, it is to be concluded that the principle of "an equal tendency to pitch and 'scend" is supported by the fact of this ship having been improved in her sailing by the abovementioned alteration in her trim.

By comparing the calculations of the *Winchester* and *President* we see a most extraordinary difference in the distances of their centres of gravity of displacement from the middle of the load water-line. Both positions for this important point or axis of the ship cannot be the best. It is probable that neither of them is the most eligible. The form of the *Winchester* makes her tendencies to pitch and 'scend much more nearly equal than the form of the *President*, whilst it is more than probable that the stowage of the latter frigate would counteract the tendency of her bottom to increase her motion of pitching, much more than the stowage of the former. And if the stowage has this effect, the pitching motion of the *Winchester* must exceed that of the *President*. The conclusion to be derived from these observations is, that it is very desirable that before constructing ships of similar size in future, the best place for the centre of gravity of displacement should be found.

In making a comparison between the two classes of 46-gun frigates and the *Inconstant* of 36 guns, now building from the design of Commodore Hayes, it will be observed that the positions of the centres of gravity of displacement in the *Seringapatam* class and the *Inconstant* are very nearly the same, and in both these vessels the tendencies to pitch and 'scend are much more nearly alike than in the *Minerva* class of frigates. If the centre of gravity of the *Inconstant* is too far before the middle of her length, and probably it is not, it may be expected she will be rather more easy in her longitudinal motions at sea than ships similar to the *Seringapatam*, and much more so than those like the *Minerva*.

If any one who has the means will make a similar series of calculations of the *Pique*, the new frigate of 36 guns which a short time since arrived at Portsmouth from an experimental cruise with the *Castor*, it will most probably be found that the reason why it was necessary to bring the *Pique*, during her trial with the *Castor*, to so much greater a draught of water by the stern than that at which she was intended to sail, is either that her centre of gravity is much too far before the middle point of her length, or that her tendencies to pitch and 'scend are very unequal.

The *Imogene*, of 28 guns, is believed to be nearly a *fac-simile* of the *Tyne*,—the ship which, with the *Sapphire* and *Challenger*, formed part of the experimental squadron of 1829. The most remarkable feature in these vessels is that of the number of tons of the displacement. If the *Sapphire*, whose total weight is 770 tons, is in all respects an efficient ship for an armament of 28 guns, it cannot be proper that the *Imogene* should have been constructed with a displacement of 103 tons more than the *Sapphire*, or that the *Challenger* should have been, under any ordinary circumstance, immersed so much as 170 tons more than the same ship. The calculations of the effects of the water on these vessels, in causing them to pitch and 'scend, show the *Sapphire* to be the most easy ship.

A comparison may now be made of the calculations of the *Rover* and *Columbine*, built on the system of Captain Symonds; the *Orestes*, constructed by Professor Inman; and the *Champion*, from the draught of Commodore Hayes. Between these vessels there is a very wide difference in the distances of their centre of gravity of displacement from the middle of the load-water line. The greatest discrepancy is between the *Columbine* and the *Champion*. The tendencies to pitch and 'scend in the *Champion* arising from the form of her bottom are very nearly alike, much more so than in either of the other corvettes. But, owing to her centre of gravity being so very small a distance before the middle of her length, the effect of the weights in her might alone cause her to pitch and 'scend with considerable violence. In the *Columbine*, on the other hand, where the centre of gravity is a very great distance before the middle, the tendency to pitch arising from the form of her bottom is very much greater than her tendency to 'scend. The *Rover* and *Orestes* have their centres of gravity in a mean position nearly between those of the *Columbine* and *Champion*, and the tendencies of the former vessels to pitch and 'scend must, if similarly stowed, be pretty nearly alike.

Nothing, it is thought, can display in a more clear and striking manner the present imperfect state of the practice of Naval Architecture than that four vessels constructed to carry the same armament should be so extremely dissimilar to each other in so many respects—in the forms of their bottoms, in their volumes of displacement, in the positions of their centres of gravity, and in the relative fulness of their fore and after bodies. Some fundamental principle is plainly wanting as a legitimate foundation for the practice of constructing ships. And that essential element is considered to be the best position for the centre of gravity through which the axes of rotation pass.

Those who construct ships by merely practical methods virtually reject and condemn as useless calculations made on scientific principles. It has, indeed, been declared that nothing relating to the performance of a ship at sea can be predicted from the results of calculations.

With just as much propriety might any one assert that he will not believe that the time of an eclipse of the sun or moon can be found by astronomical computation.

It remains merely at present to take a passing notice of the *Waterwitch*, lately purchased into the Navy, and which appears to possess very superior sailing qualities. The points in this vessel which distinguish her from others, and perhaps especially from those with which she has been placed in competition, are the proximity of her centre of gravity to the middle of her length, and the very near equality of her tendencies to pitch and 'scend.

The calculations thus briefly illustrated are a specimen of part of those which ought to be made by a Naval

Architect to ensure that, before the expense of building a ship is incurred, the structure shall possess all its desirable qualities. It is only by means of such computations, together with accurate accounts of the stowage, that the remarkable discrepancies which have been observed in the sailing of different vessels, and of the same vessels at different periods, can be satisfactorily accounted for.

These calculations also show that if ships were to be constructed according to the system propounded in my former paper in this work, they would be distinguishable from ships hitherto built, in the same manner as a just balance is distinguished from a false one: the axis of rotation would be placed where it ought to be in the one case, which it never has been in the other; and thus it is plain that all vessels heretofore built, and which are uniformly balanced on the principle of the just balance breadthways, are balanced like a false balance or a steelyard lengthways; and that, in fact, all ships (with possibly a few accidental exceptions), though not lop-sided—which they would be if both sides were not made exactly alike—are nevertheless lop-ended, in consequence of the want of a method of determining the best position for the axis of rotation.

For the sake of illustrating these observations, it may be remarked respecting the *Pique*, one of the latest constructions of the Surveyor of the Navy, as I have been led to believe, the ballast, stores, and other weights were originally stowed on board of her in the usual way, according to the discretion of some one of her officers—either her captain, her master, or the mate of her hold; and thus this ship, like others when equipped for sea, became the joint production of the

Surveyor of the Navy and the individual who directed the operation of stowing her. The *Pique*, when at sea, appears to have been found to pitch somewhat more heavily than ships in general; and in order to diminish the violence of her pitching motion, and thereby to improve her sailing, it seems to have been necessary to discharge a large portion of her sea-store of fresh water, and to remove part of her ballast, guns, &c., towards her after end, and by such means to immerse the ship about 18 inches more by the stern and less by the head than her constructor intended, and of course expected her to swim. So great an alteration made in the stowage and trim of a ship must in any instance be regarded as a very untoward circumstance: all the endeavours of the Naval Architect to produce a perfect ship being thus completely frustrated and tacitly condemned.

In conclusion, I observe that one of the great advantages which would result from the mode of construction I have thus endeavoured to elucidate would be that a simple and uniform mode of stowing ships would thereby be supplied. The stowage of every ship would be performed according to the mode prescribed by her constructor, who would first mark the vertical and transverse plan of the centre of gravity of displacement of the vessel, and then dispose of an equal weight on the fore and after sides of this plane in such a manner that whilst the whole of the stowage, and the heaviest articles especially, would be placed as near to midships as practicable, the common centre of gravity of the weights afore and abaft the centre of gravity of displacement would be at an equal distance from this point, and from the centre of gravity of the ship, or axis of rotation.

We append to this interesting paper the following remarks on it by the editor of the *United Service Gazette* for December, 1835.—EDRS. Papers on N.A.

"Considering how much the stowage of a ship acts upon the vibratory motions of a ship, and consequently should enter into all those calculations of every naval constructor who is desirous of estimating and regulating beforehand the qualities of the ship he intends to build, we have been much pleased by the perusal of an article, which escaped our notice before, in the *United Service Journal* for November last, on the true principles by which the stowage of ships should be regulated. In this country the stowage of ships has hitherto been, and especially since the reign of intuition, regarded as a kind of necromancy; but the author of the memoir alluded to divests the subject of its magical character, and brings it down to a sober mathematical, matter-of-fact, proceeding. Mr. Henwood, who has thus undertaken to enlighten the public upon this very mysterious operation, is a member of the School of Naval Architecture, and along with a scientific discussion of this question, gives a faithful and bold *exposé* of the present system of humbug, by which one man designs a ship upon what has been aptly termed 'intuitive knowledge,' and another man, equally well qualified with the former, has the stowage committed to his peculiar 'intuition' also. Thus two different persons, with independent 'intuitions,' are concerned in the putting forth of every ship to sea; and a pretty affair they generally make of it, as numerous instances, and particularly recent ones, amply prove. Mr. Henwood is not, like the intuitive clique, full of assertions and destitute of proof, but rests his conclusions upon a series of calculations made upon no less than twenty ships of the British Navy. The results, which are exhibited in a table, point out also in the most conclusive way the imperious necessity of the designer of a ship being capable of appreciating scientifically the qualities of his design and the consequences of his *modus operandi*, for without the necessary knowledge of the relation between cause and effect, how can the projector estimate or regulate the behaviour of his ship before it is built? In the most sublime ignorance which now reigns triumphantly over our naval constructive department, we behold the cause of all the vast and profligate expenditure of the public money on ships built upon mere speculation, or at best upon the poor chance that designs without calculation, or any other guarantee of success than the arrogated 'intuition' of their projectors, should end in any other way than the most disastrous failures. Can this lack, this woful lack of knowledge be much longer tolerated, with all the accumulated evidence of its evil consequences before our eyes; or is the British Navy always to be a plaything in the hands of wild and fanciful projectors? Let those answer this question who can.

"In these days, when the possession of scientific knowledge or an honest declaration of the truth is the most likely means of keeping a man from preferment, Mr. Henwood deserves a double portion of praise for his scientific discussion of the important question of the stowages of ships, and for the fearless manner in which he has published the conclusions at which he has arrived, however unwelcome they may be to 'intuitive' ears."

Art. XXIII.—*Description of the* Affondatore, *Iron Armour-clad Turret Ship, of the Royal Italian Navy.* By Charles F. Henwood, N.A., East India Avenue, London.

As a good deal of attention has been attracted to this vessel during her building, I have thought a description of her would not be uninteresting; but before describing her I consider it right to state the circumstances under which I designed her, because she is not such a vessel as science and experience can acknowledge as being in accordance with them in regard to the proportion of length to breadth and the position of the turrets. Both of these elements were dictated by the Italian Government, and I need hardly say they constitute the principal elements on which to a great extent her qualities depend. Plate V. is a representation of her as built. Plate VI. shows arrangement of turrets as proposed by me to the Italian Government, but not approved of by them. I shall presently speak more particularly as to the arrangement of the turrets, but will now proceed with a description of her construction. Her principal dimensions are as follows, viz.:—

	feet.	in.
Length between perpendiculars ...	295	0
Breadth, extreme	40	0
Depth in hold........................	19	6
Load draught	20	0
Burthen in tons	2,306	0
Nominal horse-power	700	0

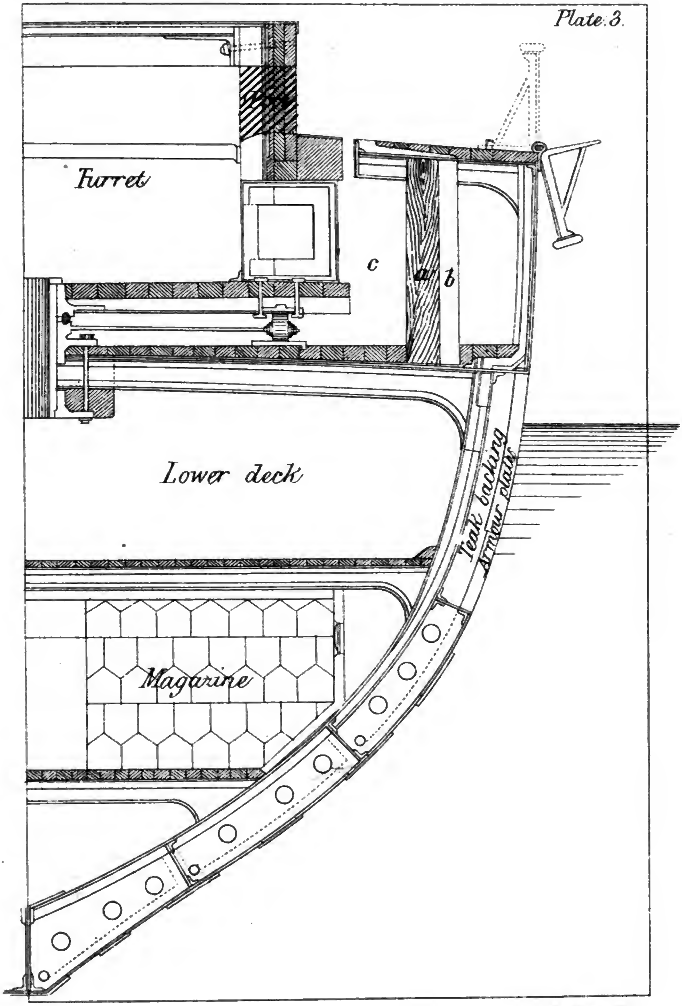
Her keel was laid by me on the 1st December, 1862, when holding the position of Naval Architect and Master Shipbuilder of the Millwall Iron Works and Shipbuilding Yard. She was launched on the 4th November, 1865, in a forward state of completion.

The construction of her hull-framing is a modification of the system adopted in the *Warrior* and the other British iron-clads (see Plate III.), but proportionally lighter and less complicated. The bottom plating of the hull is generally about $\frac{11}{16}$ in. thick, the keel-plate $\frac{3}{4}$ in. thick, the webs of the frames are $\frac{1}{2}$ in. thick, the frames being only 21 inches apart from centre to centre.

There is much of the *Monitor* character embodied in this vessel; indeed, if all her upper unprotected works were shot away she would present the appearance of a veritable *Monitor*, the main deck being entirely plated over with two thicknesses of plates 1 inch thick, and the armour-plating, which is generally 5 inches thick, extending from the main deck to 7 feet below the load-water line, and extending entirely round the vessel, but tapering in thickness at the extremities; the hatches and openings on the main deck are also protected by strong bars, made to shift, which are intended to prevent shot or shell entering below this deck.

The turrets, which are on Captain Cowper P. Coles's patent, are intended to carry one Armstrong 300-pounder each, and are placed near the extremities of the vessel, as shown in Plate V.; they are protected between the upper and main deck by a circular wall or bulkhead of teak 15 inches thick (*a*), and plated with armour-plates 5 inches thick (*b*) (see *a* and *b*, Plate III., p. 276A). Between the inside of this wall and

"Affondatore" Section at Foremost Turret.



to face p. 276

the turret there is room left for a passage (*c*) for the men working the turret and serving the gun; there is also direct communication from inside this wall and the turret to the lower deck; also, a doorway is left in this wall on the after part of the foremost circular wall and the fore part of the aftermost circular wall.

By this arrangement of the turrets the boilers are not so thoroughly protected as they would have been by the arrangement shown in Plate VI., where, instead of the turrets being protected by a circular wall, the armour-plating of the ship's side would have been carried up to the upper deck, the ends being protected by athwartship bulkheads armour-plated. No danger would then exist of a shot entering the boilers, and by this arrangement greater accommodation would have been afforded around the turrets.

The stem or ram, deserves notice from its great length, projecting 20 feet, but is not of the "plough" form, about which so much has lately been said. The idea of having such a "beak" was to ram at the propeller of an enemy; but I am of opinion it will not be found of much service as a ram, and such a projecting beak under water is of no benefit to the ship, nay, rather is injurious.

Since she was designed two additional boilers have been added to increase her horse-power, which additional weight has been, I believe, compensated for by a reduction in the thickness of some of the armour.

The desire of the Italian Government to obtain a fast and powerful armour-clad vessel will be realised, but not to so great an extent as would have been the case had I not been restricted to the dimensions, position of the turrets, and the projecting stem or ram; but in armament she will throw a broadside of 600 lb., whilst the *Defence*, of 3,720 tons burthen, can only throw from her broadside of protected guns 560lb.; and whilst the *Defence* steams but 11·618 knots, the speed of this vessel is estimated at 14·5 knots, but she will not be so good a sea-boat as the *Defence*. She will be very fast in smooth water, but will labour heavily in a sea. As she is intended for the Mediterranean, where it is generally calm weather, she will probably realise the expectations of the Italian Government; but a vessel similarly armed and arranged, as in Plate VI., with a better proportion of breadth to length, would, I believe, prove a most effective cruiser for the British Navy.

The position of the turrets, as in Plate No. V. (as built), tend to strain the ship greatly in a sea, and have five times greater effect in producing uneasy motion of the ship than if arranged as shown in Plate No. VI.

Art. XXIV.—*On Pitching.* By the late William Henwood, Esq., Member of the late School of Naval Architecture. An unpublished Manuscript, dated Malta, 1850.

The pitching motion of ships is doubtless in some degree dependent on the positions of the disposable weights, such as the ballast, shot, chain cables, &c., and it is evidently a defect in the theory of Naval Architecture that no rule or principle has been laid down for the stowage of those weights, with a view to their producing an advantageous effect on the longitudinal motions.

The want of such a principle is probably attributable to the conflicting opinions which have been held by distinguished mathematicians from the time of Descartes, Newton, and Leibnitz, on the subject of the "moving force" of weights in motion. Professor Barlow, in his "Mathematical Dictionary," has given the following remarkable account of the controversy on this highly important mechanical subject.

Concerning the measure of "moving force" mathematicians have been divided into two parties. It is allowed on both hands that the measure of this force depends partly on the mass of matter in the body, and partly upon the velocity with which it moves: the point in dispute is, whether the force varies as the velocity, or as the square of the velocity.

" Descartes and all the writers of his time assumed the velocity produced in a body as the measure of the force which produces it, and observing that a body in consequence of its being in motion produces changes in the state or motion of other bodies, and that these changes are in the proportion of the velocity of the changing body, they asserted that there is in a moving body an inherent force, and that this is proportional to its velocity, saying that its force is twice or thrice as great when it moves twice or thrice as fast at one time as at another."

But Leibnitz observed that a body which moves twice as fast rises four times as high against the uniform action of gravity; that it penetrates four times as deep into a piece of uniform clay; that it bends four times as many springs, or a spring four times as strong to the same degree; and produces a great many effects which are four times greater than those produced by a body which has half the initial velocity. If the velocity be triple, quadruple, &c., the effects are 9 times, 16 times, &c., greater, and, in short, are proportioned, not to the velocity, but to its square.

This observation had been made before by Dr. Hooke, who has enumerated a great variety of important cases in which this proportion of effect is observed. Leibnitz therefore affirmed that the force inherent in a moving body is proportional to the square of the velocity, and the same principle was adopted by Wolfius, the Bernouillis, and many other mathematicians.

Leibnitz's first paper on this subject was published in the "Leipsic Acts" for 1686, and was answered by Catalan and Papin; from which time the dispute became very general, and was carried on for several years between Leibnitz, John and Daniel Bernouilli, Poleni, Wolfius, Gravesand, Camus, Muschenbrock, &c., on the one side, and by Pemberton, Eames, Desagnliers, Clarke, Mairan, Jurin, Maclaurin, Robins, &c., on the other; Newton having prudently avoided entering at all into the controversy.

Barlow himself has taken the Cartesian side of the controversy, and says "that the Leibnitzian measure of moving force obliges us to do continual violence to the use of words," and in support of this statement he adds that "when two bodies moving in opposite directions meet, strike each other and stop, all men will say that their forces are equal, because they have the best test of equality which we can devise. Or when two bodies in motion strike the parts of a machine, such as the opposite arms of a lever, and are thus brought completely to rest, we and all men will pronounce their mutual energies by the intervention of the machine to be equal. Now in all these cases it is well known that a perfect equality is found in the products of the quantities of matter and velocity. Thus a ball of two pounds moving with a velocity of four feet in a second, will stop a ball of eight pounds moving with a velocity of one foot per second. But the followers of Leibnitz say that the force of the first ball is four times that of the second."

The above statement of Professor Barlow, that "in all these cases it is well known that a perfect equality is found in the products of the quantity of matter and the velocity," is simply a begging of the question in dispute. The exact measure of velocity is generally a very difficult matter, which it does not appear that Professor Barlow has attempted, but has contented himself with a gratuitous assertion, which by no means strengthens the Cartesian argument.

It is perhaps, as Barlow has stated, "vain to attempt to support either of the two measures of moving force by a demonstration;" and therefore we are led to endeavour to find from experiment that which reasoning appears inadequate to supply—viz., a solution of this very important question.

Before being aware of the great difference of opinion amongst mathematicians on this important practical question, or that, as Barlow states, the conclusion of the Cartesians has been adopted by all the most eminent authors of the present day, I had made experiments to ascertain the comparative moving forces of two weights turning on an axis, one being twice as far from the axis as the other, and moving with twice the velocity.

A block of wood, of uniform density and free from knots, was selected, and holes bored through it half an inch in diameter with a machine; two bolts 10 inches long and $\frac{5}{8}$ of an inch in diameter were cut from the same copper boltstave, their ends carefully smoothed alike and driven each exactly two inches into the holes bored through the block. Two mauls, each of 13lb. exactly, were fitted to revolve on an axis, one at the distance of 3 feet from the axis to its centre, and the other at the distance of 6 feet, and so as to fall on the bolt in the block, the centre line of the maul falling in the centre of the bolt.

The maul with the 3 feet radius was made to fall eight times through one foot, measured vertically, on one of the bolts, which was thus driven $\frac{15}{16}$ of an inch further into the block, and the other maul with the 6 feet radius was then made to fall upon the same bolt from a height measured vertically of 4 feet, to insure its acquiring exactly twice the velocity of the other at the instant of striking, and the effect of falling twice from the height of 4 feet on the same bolt was that it was driven $1\frac{2}{16}$ inches farther into the block.

The latter maul was then made to fall vertically 4 feet on the other bolt twice, which was thus driven $1\frac{4}{16}$ inches farther into the block, and then the first maul was made to descend eight times, one foot, on this bolt, which was thus driven $\frac{14}{16}$ of an inch more into the block. The joint effects produced on each of the bolts were accordingly that they were driven $2\frac{1}{16}$ and $2\frac{2}{16}$ inches; and in both cases the effects produced by the long maul were more than four times those produced by the short one. This experiment was repeated several times, and very nearly the same result was obtained in each instance,—the above being a mean result of many trials. It was thus shown that the weight at the distance of 6 feet from the axis produced more than four times as great an effect in each case as the weight at 3 feet from the axis. And as the velocity of the former at the instant of striking the bolt was precisely double that of the latter, this and every other similar experiment fully confirmed the truth of the law which Leibnitz appears also to have derived from actual experiments—viz., that the effects produced by weights in motion are in proportion to the square of the velocity, and not to the velocity simply.

It accordingly appears that if in a ship one weight is 40 feet before the transverse axis, and another equal weight 80 feet, the latter will produce four times as great an effect in increasing the pitching motion as the former; and thus the great importance of concentrating the weights of a ship as much as possible is clearly shown.

Another difficulty has been raised by scientific individuals respecting the effects of weights which are abaft the transverse axis on the pitching motion, compared with the effects of weights which are before the same axis. It is avowedly held by every one, that whilst the ship floats at rest, the weights before the axis counterpoise the weights abaft it; but it is or has been maintained that it is altogether different when a ship is pitching, as she then turns on her transverse axis, and the weights abaft the axis are made to revolve in the same direction as the weights before it, "like the parts of a fly-wheel;" and thus it has been said, every weight, both those before the axis and those abaft it, have a like tendency to increase the pitching.

With a view of testing this question, another experiment has been made, by which some effects which balancing weights before and abaft the transverse axis have on the rotary motion of pitching are clearly shown.

Two bars of iron have been fitted to revolve on an axis, one bar twice as long and half as heavy as the other, the long bar having an equal weight at each end, and the short bar having also a weight at each end twice as heavy as the weights on the long bar, but fixed at half the distance from the axis: thus either arm of one bar would in a state of quiescence balance either arm of the other, their moments being equal, each to each.

When those bars are made to revolve by an equal moving force, it is found that a greater velocity of rotation is produced with the short bar than with the long one at the commencement of the rotation; but the double weight of the short bar, causing twice as much friction on the axis as that caused by the long bar, the more rapid revolution of the short bar is quickly reduced, and the less rapid rotation of the long bar is diminished slowly.

It is apparent from this experiment that if there was no friction on the axis, as is the case with a ship, the short bar would continue to revolve with greater velocity than the long one for an indefinite period. And this result is in perfect accordance with mathematical investigation, which shows us that the farther balancing weights on a lever are from the axis the more *slowly* will the lever revolve when a given force is applied, and it is also confirmed by the well-known practice in ships with much ballast of winging the weights to make them roll slowly.

It is accordingly conclusive from experiment, from science, and from facts, that the farther aft balancing weights can be placed in a ship, the slower will be the pitching; and it follows that if the pitching be slow as the ship continues to move ahead whilst she is pitching, the less will be the immersion of the bow and the greater the velocity of sailing.

But perhaps the question whether the weights abaft as well as those forward contribute to produce pitching, just as the parts of a revolving fly-wheel, may be met in a more direct manner.

If pitching could be viewed simply as the rotation of a ship on her transverse axis, a comparison with the rotation of a fly-wheel might be admitted. But as pitching is, in fact, the descent of the fore part of a ship in an inclined direction into the hollow of a wave, rather than a rotation on her transverse axis, and as the centre of gravity, instead of being fixed as in a fly-wheel, descends also, the comparison of pitching with the rotation of a fly-wheel is clearly a fallacy; because the weights before the axis are more depressed by the pitching than the weights at corresponding distances abaft are raised by it; and thus the former weights acquire a greater velocity and force of motion downward than the latter can acquire in the contrary direction, which is not the case in the rotation of a fly-wheel.

As the bowsprit of a ship, with its booms and rigging, extends much farther before the transverse axis than any counterbalancing weights are abaft it, the bowsprit, &c., must acquire a greatly preponderating force of motion in pitching, and must produce a corresponding immersion of the bow; and it is doubtless owing in part to the weight of the bowsprit,

&c., being so much farther before the transverse axis than any weights are abaft it that the 'scending motion is so much less than the pitching in ships generally, and thus it appears that if a weight like a bowsprit, &c., *were* required to be carried at the stern, the pitching would be made slower, and also be reduced.

The object in view being to find a practical remedy for the fault of violent or deep pitching, when a ship is found to have this fault, it is conclusive from the above remarks that the most direct and effectual remedy for pitching would be to stow weights as far aft as possible.

If shot were to be stowed at the after part of the bread-room and low down, some other weights being removed from aft farther forward so as to keep the water-line of the ship unaltered;—for example, perhaps 15 tons of shot might be stowed in a large ship low down at the after end of the bread-room, and if 15 tons of shot were moved 100 feet aft, and 100 tons of ballast, chain cables, shot, or other weights, were moved 15 feet farther forward, the trim of the ship would remain unchanged, and a considerable diminution of pitching might be obtained.

Should such a disposition of weight be viewed as opposed to general opinion, it may be worth consideration that the 74-gun ships fitted with the screw propeller do not appear to have been injured by it, although the loss of from 25 to 30 tons of displacement in cutting the aperture, and the addition of 18 tons of metal castings, are together equivalent to some 45 tons of dead weight at the after extremity.

An experiment of placing 15 tons or even more in the bread-room may, therefore, as both experiment and mathematical reasoning lead us to expect, be found to be a remedy for the fault of excessive pitching, and may prevent in part, if not entirely, a loss of velocity in a head sea.

ART. XXV.—*The American Lake Navigation.* By HENRY JONES, Esq.

1. "The Colonial Policy of Great Britain considered with relation to her North American Provinces." London: Baldwin, Craddock, and Joy, 1816.
2. "Reports of the Chicago Board of Trade," 1862—1864.
3. "Hunt's Merchants' Magazine." New York, 1866.
4. "The Canadian Canals." Toronto: Rollo and Adam, 1865.
5. "Hunter's Guide from Niagara to Quebec," 1865.
6. "The International Trade of the United States, England, and Canada." By P. Barry. Chicago: D. B. Cooke and Co., 1858.

The question of the American lake navigation will be brought before Parliament in connection with the well-known scheme of confederation; the condition and prospects of the lake navigation being such as to enlist the liveliest sympathy of commercial men. In its present state, the American lake navigation is probably of greater importance, that is, in respect to the number of ships employed and the quantities and values of the commodities carried, than the entire home and foreign commerce of France, or any other continental country. It is entitled to rank after the United States carrying trade and our own; second, in relation to that of the United States, and third, in relation to our own. And this magnitude, as will be presently perceived, has been achieved under great disadvantages. There have been shallows, and rapids, and small canals, and, last but not least, a difficulty in negotiating the drafts which are a condition of foreign commerce. Mr. Barry resolutely attempted to bring the North-Western States into direct intercommunication with Europe, but failed, through the novelty of the enterprise and the large amount of accommodation that it imperatively required.

When the jealous opposition of New York shall have been overcome, and the North-West is able to buy and sell in the great markets of the world, without the intervention of various sets of middlemen, it is impossible to estimate the prospective bulk of the lake trade; for all the existing difficulties of navigation admit of being speedily removed. It will in time, no doubt, be a greater carrying trade than that of the United States, and may even exceed that of the United Kingdom.

Rather oddly, as will appear to most people, the development of the American lake trade was retarded by a similar bugbear to that which prevailed with respect to Malta, under the Treaty of Amilus. If that treaty had been fulfilled, the French were to obtain possession of the island, then get hold of Egypt, and afterwards attack India; no consideration being given to the successive assertions of power needful to the success of such an enterprise. The French would have had to occupy Malta in great force; to have been able to put to sea against our fleets; to have conquered Egypt; to have been sufficiently strong in Egypt to venture on an Indian attack; and, finally, to have attacked India in such overwhelming numbers as to have for ever routed us. The American bugbear was quite as monstrous, quite as strong an imputation on the common sense or the sanity of our fathers. The Americans were to annex the lakes, the St. Lawrence River, the Canadas, and anything else they cared for; and the Treaty of Ghent had brought about the evil. That treaty was a shameful sacrifice of the birthright of coming Englishmen through all generations. The "British Traveller" in the volume published by Messrs. Baldwin, Craddock, and Jay in 1816, thus speaks at page 213:—

"On a review of what has been advanced it will appear that the United States are attempting to rival Great Britain in manufactures, and that they entertain ambitious projects for the purpose of effecting her final overthrow.

* * * * *

At page 215—"The British public is therefore most earnestly requested to consider these things calmly, and to divest themselves of those fatal partialities which fettered the arms and councils of the nation throughout the late war, and which produced the most baneful consequences in the treaty of peace. If there ever existed a time that calls for unusual vigour, jealous scrutiny, vigilance, and caution in our national affairs, that period is now arrived. In consequence of the ratification of peace, the secret operations of emissaries will soon commence. The rival is about to adopt her old system of undermining the best interests of the country under the specious garb of amity. The tocsin of alarm must therefore be rung out, and seasonable antidotes provided for the poison; true patriots must see the necessity of ceasing to regard

Americans as part of the British family; they must in future be regarded in the same light as Frenchmen or Spaniards—that is, *as enemies* by birth and education—determined rivals, possessing many qualities to make them dangerous; and now that the effects of peace appear in a renewal of the accustomed intercourse between the two nations, let there be an end of that fraternisation and ingenuous frankness which on many occasions laid this country open to the machinations of her foes. Let it be repeated, even though the sound should prove ungrateful—let the voice of truth be heard which proclaims '*that Britain never had an enemy so much to be dreaded as the United States*'—never was there a foe until now that possessed her language, that master key to her councils: never until now could a foreigner introduce himself unnoticed into the British Parliament, army, navy, or manufactory, to sound her policy, learn the arts of war and peace, to employ these acquisitions against the source whence they were derived."

* * * * *

At page 221—"The insolent temerity and daring enterprise even of American privateers must not be overlooked, since it may serve as a proof of the ability of an American navy to inflict a severe wound on the British Empire. It is a fact, alas too true, that the *Scourge* and several other privateers actually chose the Irish Channel as a cruising station, and remained there for a considerable time to the great annoyance of the trade to Greenock and Liverpool; and one, cruising off the Holmes in the British Channel, took a merchant ship of Bristol, released the prisoners, and sent them on shore with an American newspaper and the captain's compliments to an individual in the city. Another attacked a transport close in with the Sambro Lighthouse at the mouth of Halifax Harbour; but being beaten off after a gallant resistance, was chased for upwards of forty-eight hours by the *Nymphé* frigate, carrying royals and skyscrapers, with lower, topmast, topgallant, and royal studding sails; the privateer all the time being under easy sail, and sometimes even with reefed topsails, keeping exactly out of the range of the frigate's shot, but capable of running her hull down in a short time. The natural inference to be drawn from the above facts is that unceasing vigilance must be exercised, since the United States fleet is really capable of striking some alarming blow; and the daring exploits of her sailors (no matter whether native Americans or British) have been such as to prove that they will readily attempt any enterprise however hazardous."

Such was the Anglo-American *entente cordiale* of 1816, and as the prejudices of a generation usually linger until the generation has died out, the American lake trade was long in starting, and still longer in being of much account. At length British adventurers found their way to Canada, and to the American States which skirt the lakes, and the getting of their produce to market wrought change. There were canals constructed, there were deepenings of shallows, and piers and harbours, and in time a considerable fleet of United States and Canadian vessels. At present, or rather at the close of 1863, the statement of the commerce of the lakes was as follows:—

Summary for the Year 1863.

	No.	Tonnage.	Crew.
American vessels entered ...	1,584	1,881,096	14,954
Foreign vessels entered	696	63,243	3,616
Coasting vessels entered.....	5,370	1,928,747	60,188
Total entered for the year ...	7,647	8,378,086	78,758
American vessels cleared ...	1,680	1,858,751	14,887
Foreign vessels cleared	640	67,988	8,647
Coasting vessels cleared......	5,409	1,958,183	60,123
Total cleared for the year ...	7,729	8,879,817	78,657
Grand total for 1863	15,876	6,757,903	157,415
„ 1862	16,390	6,689,191	166,133
„ 1861	18,866	5,963,896	144,173
„ 1860	11,527	4,710,175	120,497
„ 1859	10,521	5,592,626	118,109
„ 1858	8,218	3,320,246	86,887
„ 1857	7,581	3,226,807	132,183
„ 1856	8,128	3,018,589	112,054
„ 1854	8,911	3,990,284	120,838
„ 1853	8,298	3,252,978	128,112
„ 1852	9,441	3,092,247	127,491

The limits of the trade are from Lake Superior and Lake Michigan to Montreal and Quebec, an extreme distance of 1,500 miles. From Quebec to Montreal the navigation is uninterrupted, and the shallowest part is Lake St. Peter, a lake 25 miles in length by 9 miles in width. The minimum depth of the lake is 20 feet. At Montreal the Victoria Bridge of the Grand Trunk Railway crosses the St. Lawrence River, and the rapids of the river are avoided for 8½ miles by the Lachine Canal. Beyond the extremity of the Lachine Canal stretches Lake St. Louis, a lake 12 miles in length by 6 miles in width. Then again the

St. Lawrence Rapids are encountered and overcome by the Beauharnais Canal, which is 11¼ miles in length. That canal, by the way, was foolishly formed on the United States side of the St. Lawrence River, and is therefore peculiarly exposed to attack and destruction in a time of war. Beyond the extremity of the Beauharnais Canal is Lake St. Francis, 25 miles in length by 5½ miles in breadth. Then the rapids, which form the boundary between the United States and Canada, at latitude 45°. Those rapids are overcome by the Cornwall Canal, which is 11½ miles long. Then follow a number of short canals—the Farrans Point, 3½ miles long; the Mariatown, 4 miles long; the Gallops, 2 miles long; and the Point Cardinal, 1 mile long. No further obstacles intervene to Lake Ontario. The class of vessels navigating to this point does not exceed 180 feet in length by 30 feet in breadth, and measures 550 tons. *Her Majesty*, a screw of these dimensions, built at Toronto, cost 52,000 dols. Her outlay per day for crew and fuel is 85 dols. Drawing 10 feet 6 inches she carried 7,000 barrels of flour, or 26,000 bushels of grain. Drawing 9 feet for the St. Lawrence canals she carried 4,400 barrels of flour, or 16,000 bushels of grain. Drawing 10 feet for the Welland Canal she carried 6,500 barrels of flour, or 24,000 bushels of grain.

The Welland Canal connects Lake Ontario with Lake Erie, avoiding the Falls of Niagara. The length of the canal is 28 miles, and the locks are 27 in number, rising to the Lake Erie level of 330 feet above Lake Ontario. Beyond the Welland Canal there are no other canals, unless a short one leading into Lake Superior; but there is barely 11 feet of water on the long flats which connect Lake Erie with Lake Huron. This absence of canals removes the limitation with respect to dimensions and tonnage for exclusive navigation above the Welland Canal; and accordingly a larger class of screws and sailing vessels is to be found trading chiefly between Buffalo on Lake Erie, and Chicago on Lake Michigan. One of the largest is the bark *Western Metropolis*, of 1,341 tons. As showing the classes and average tonnage, it may be stated that in 1864 the various following vessels entered the port of Chicago:—

THE SEPARATE ENTRIES AT CHICAGO, 1864.

	No.	Tonnage.
Paddle steamers	5	3,315
Screw steamers	68	37,535
Barques	92	52,193
Brigs	49	15,100
Schooners	457	115,827
Total of individual vessels		223,970

The following figures are important, as showing the movement of grain eastward on the lakes, from 1856 to 1863, compiled by the Buffalo Board of Trade:—

MOVEMENT OF GRAIN.

Year.	Flour.	Wheat.	Corn.	Other.
	Barrels.	Bushels.	Bushels.	Bushels.
1856	3,865,000	19,505,000	14,282,000	4,592,000
1857	3,397,000	16,763,000	8,779,000	2,256,000
1858	4,499,000	21,843,000	10,495,000	5,035,000
1859	3,760,000	16,865,000	4,423,000	5,264,000
1860	4,106,000	32,000,000	18,075,000	7,712,000
1861	6,533,000	46,384,000	29,524,000	10,656,000
1862	8,433,000	51,220,000	32,998,000	11,286,000
1863	7,782,000	36,513,000	24,955,000	15,983,111

At the principal receiving points the grain receipts were in the following proportions:—

RECEIPTS, 1858—1863.

	1858.	1859.	1860.	1861.	1862.	1863.
Buffalo..............	47·1	50·0	47·2	51·5	52·8	55·6
Oswego	19·2	17·1	21·7	15·5	13·3	12·4
Montreal	9·2	8·7	9·2	12·6	13·09	11·8
W. Ter., Buffalo, & Oswego Railway	6·5	5·7	2·4	3·0	2·9	3·6
W. Ter. Panama Central Railway	4·3	4·2	3·9	4·1	4·4	5·2
Ogdensburg.........	6·0	5·8	3·5	3·1	3·42	3·48
Dunkirk	3·4	5·6	4·2	3·8	4·1	3·0
Suspension Bridge..	2·0	0·7	6·5	5·4	5·1	4·5
Cape Vincent	1·8	1·3	0·8	0·6	0·7	0·35
Rochester...........	0·5	0·9	0·6	0·1	0·19	0·17
	100·0	100·0	100·0	100·0	100·0	100·0
Per cent. of receipts at Buffalo and Oswego	66·3	67·1	68·9	67·0	66·1	68·0
All other points	33·7	32·9	31·1	33·0	33·9	32·0

One English ship, the *Madeira Pet*, has made the out and home voyage to Chicago. From the Mersey to Montreal occupied 35 days, and from Montreal to Chicago 45 days, or 80 days in all. The terms of the charter-party were 30s. (7.26 dols.) per ton, of 2,240 lb., or 40 cubic feet, to Montreal, and from Montreal to Chicago and back to Montreal £4 daily. From Montreal to Liverpool, 9s. per quarter for wheat. The outward log was as follows:—

April 24. This day, at 10 a.m., pilot came on board, weighed, and made sail, and proceeded down the Mersey. At 4 p.m. light airs and thick. At midnight found the ship drifting too close to shore—let go the anchor for the remainder of the tide. Pumps attended to.

April 25. At 6 a.m. weighed and made sail and proceeded on the voyage—ship drifting back with the flood. At 6.30 p.m. stiff breezes with drizzling rain.

April 26. Stiff breezes and cloudy. This day noon commences sea log.

April 27. Gentle breezes and fine clear weather.

April 28. Variable winds and fair weather. Employed in getting anchors on board and stowed and unbent the cables and put them below.

April 29. Tacked the ship to the westward—stormy winds and cloudy.

April 30—May 2. Stiff breezes; all sail set to the best possible advantage. Lat. 48·53, long. 20·07 W.

May 3. All sail set. At 8 p.m. wind increased; carried away the square-sail sheet. Replaced and set it again. Midnight squally.

May 4. Short cross sea—several ships in company.

May 5. Light winds with long swell from the northward; carried away main boom top and light. Replaced again.

May 10—11. Winds favourable throughout—squally and weather disagreeable.

May 16. Passed several icebergs.

May 24. At 4 p.m. saw the land bearing N.W. At 8 o'clock saw St. Paul's Island bearing N. by E.—distant about 7 miles.

May 31. Received pilot on board.

June 1. At noon at Quebec.

June 3. Came on to Montreal.

June 4. Received orders to haul the ship into the canal and proceed to Chicago.

June 5. Aground, not able to haul the ship through.

June 12. Through canals; entered Channel of Thousand Islands. At noon came to Kingston. Took pilot to Chicago.

June 14. Off Presque Isle. Light winds.

June 15. Arrived at the entrance to the Welland Canal.

June 19. In canal. Schooner *Massilon* ran foul of us.

June 20. Getting ship ready for sea.

June 22. Proceeded on the voyage. Wind westerly.

June 24. Calm and clear weather; tacked ship occasionally.

June 25. Still calm; heavy fogs; employed in painting ship.

June 26. At 6 p.m., Point au Pelee Light distant five miles. Light winds.

June 27. Arrived at Detroit.

June 28. Cook deserted the ship during the night; weighed, made sail, but not sufficient wind to stem the current.

June 29. Light winds and calm; strong current making down.

June 30. Weighed, made all possible sail—entered Lake St. Clair. At 2 o'clock came to in 11 feet of water, owing to the wind getting high and inclining to the northward. At 3 o'clock weighed—strong winds from the westward. At 4 o'clock got into St. Clair River—all possible sail set. Wind too light to stem the current.

July 1. Steam-tug towed ship. Left at Newport to tow other ships over the flats.

July 2. Proceeded in tow of tug at 4 30 p.m. Left in Lake Huron—set sails in first reef—short sea winds N. by W.

July 3—6. Weather hazy, with repeated calms.

July 7. Stiff breezes with thick haze; entered the Straits of Mackinac.

July 8. Light winds, calms, thick fogs. At midnight off Maniton Islands.

July 9—11. Light breezes.

July 12. Off Milwaukee; strong winds and storm.

July 13. Light winds; stormy breezes; plying to windward to the best advantage.

July 14. At 8 p.m. off Chicago harbour. Sailed up channel and came to North Pier.

Copy of manifest of cargo on board the British schooner *Madeira Pet*, of Guernsey, 123 tons, from Liverpool to Chicago. Wm. Craug, Master :—

1,609	bars iron.	5	casks earthenware.
170	bdls. do.	5	tons pig iron.
19	casks glass.	200	kegs paint.
1	case samples.	150	,,
20	casks hardware.	150	,,
1	crate hardware.	140	,,
8	cases steel.	7	casks paint.
107	crates earthenware.	7	,,

Such was the dreary voyage of a small ill-adapted schooner, against the twelve-day voyages of screw-steamers from Chicago to Quebec, inclusive of the delays in the Welland Canal. Sailing ships must be of different proportions and with different bottoms—with lifting keels or centre boards—to perform the work with profit. The disappointments attending the disposal of the *Madeira Pet's* cargo, and the equally great disappointments in the obtaining of a return cargo, damped—or rather destroyed—the ardour of those interested in the voyage. There was a dead loss of several thousand pounds. But such things will happen, and must indeed be looked for, in the opening of a new trade. A well-organised company, with the right sort of ships, on the lakes, transhipping into ocean steamers at Montreal, would probably be the best beginning; but with the enlargement of the St. Lawrence Canals, the enlargement of the Welland Canal, and the deepening of the St. Clair flats, the largest class of ocean ships and steamers might safely and profitably undertake the voyage.

ART. XXVI.—*Miscellaneous.*

THE WOOLWICH AND WATERMAN STEAM-PACKET COMPANIES.

TRADE is justly due to a company who are anxious to afford accommodation to the public of the best description, and no doubt these companies, acting wisely and in the spirit of the age when by public advertisement they offered a premium and invited naval architects and others to send in designs for vessels considered most suited for their service on the Thames below London-bridge. It was to be expected, notwithstanding the smallness of the premium offered, that numerous designs would be sent in. The expectation of the companies was, we believe, fully realised, the number of designs amounting, we understand, to little short of one hundred, which were delivered on the 20th September, and we are informed that it was at the time suggested to the directors that after they had made their selection the designs should be thrown open for the inspection of the public, as is the invariable custom on all similar occasions, but we regret to say the directors on this occasion took no notice of the very proper suggestion made to them, and, after a period of six weeks, a circular letter without even thanks was sent to each contributor, merely intimating that the directors had selected the design of one of the contributors and that the others could have theirs back again by sending for them.

We can hardly credit a public company acting in such a manner. The contributors have certainly just grounds for complaint, and more especially as we are informed that the design selected is acknowledged by a director to be totally unfit for the service.

Such matters as these should in all cases be done openly and in good faith with those gentlemen who may put themselves to the trouble and expense of sending designs in answer to public invitation by advertisement.

* * *

It is stated that the United States have already four fast *Gunboats* afloat on Lake Erie, costing nearly £40,000 each.

* * *

The following description by the *Times* of the attempted rectification of an expensive Admiralty *blunder* is so rich that we give it in full:—

"The work of fixing the light iron bulkhead to the iron-clad frigate *Bellerophon*, 16 guns, 1,000-horse power (nominal), is being carried out in No. 3 Dock at Chatham. In addition to clearing the forecastle of the seamen's closets, hammocks, &c., the new head will possess the great desideratum of serving as a cutwater to divide the tremendous wave which the tremendous underwater, cleaver-shaped prow ploughs up when the frigate is being driven through the water at full steam, and which was so apparent on the occasions of the recent speed trials of the *Bellerophon*, when the water was thrown up in comparatively smooth seas as high as her hawse pipes. The iron head which fills up the space caused by the projecting prow and the receding stem will be purposely kept short so as not to weaken the effect of the blow which the *Bellerophon* would deliver against an enemy under ordinary circumstances, while at the same time it would be easily crushed up in the event of a very violent collision.

"Provision for the additional head was made in the original designs for the frigate received at the Dockyard, should it be found desirable to adopt the same. The screw blades of the four-bladed propeller have been unshipped and their pitch altered to one of 18 feet 6 inches. It is also intended to fit the frigate with a two-bladed screw now being prepared for her; but it is not expected that the new screw will be completed and fitted in sufficient time to enable the frigate to be ready for another trial of her machinery by the approaching spring."

* * *

Instructions have been received at Chatham Dockyard from the Admiralty as to the two new vessels ordered to be built from Mr. E. J. Reed's designs, viz., the *Hercules* and the *Blanche*, the former being an entirely new kind of ironclad, to be coated with armour-plates of great thickness, and the latter an improved frigate (unarmoured) of the *Amazon* class, and intended to carry a battery of a few guns of the heaviest calibre. The *Hercules* will be constructed with a thickness of iron running along her broadside of 11¼ inches, of which her armour-plates alone will be of the enormous thickness of 9 inches, or exactly double the thickness of the armour-plates of the *Warrior*. On the occasion of the experiments on the *Hercules* target made at Shoeburyness, the Armstrong 12-ton 300-pounder shunt guns were fired at a distance of only 200 yards, with charges varying from 45lb. to 60lb. of powder. Although a steel shot of 300lb. weight and 10½ inches in diameter struck the centre of the 9-inch armour-plate with a velocity of

The most efficient transport in the navy was the *Himalaya*, recently put out of commission to undergo repairs. She was purchased from the Peninsular and Oriental Steam Navigation Company, after making a few voyages to Alexandria. She is now about 15 years old, and has been in active service nearly the whole of that period.

In 1861	she travelled	16,910	miles, consuming	5,142	tons of coal.
1862	„ „	25,470	„ „	6,909	„
1863	„ „	39,635	„ „	7,338	„
1864	„ „	28,664	„ „	5,241	„
1865 ending Oct.		24,734	„ „	5,724	„

Average speed of ship 10·2 knots = 12 miles an hour nearly.

The average consumption of coal for every 5 miles run was 22½ cwt., as above.

Her trial of speed in 1856 at the measured mile was 12·9 knots.

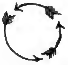
The *Royal Sovereign* 5, turret ship, Captain A. Herbert, on Friday and Saturday the 17th and 18th November, completed a very satisfactory course of experimental firing from the two guns in her forward turret in testing the new winch purchases fitted to the guns, under the superintendence of Capt. C. P. Coles, outside the Isle of Wight, a considerable sea running, the roll of the ship being—*maximum*, 16 deg.; *minimum*, 6 deg. The turret worked with the same facility and steadiness which have always been experienced under all conditions of weather with the guns at practice. The winch purchases, for the trial of which the experimental firing was made, proved perfectly successful in their fitment, and capable of maintaining full control over the motion of the 12-ton guns with the ship rolling at the *maximum* point of 16 deg. At this roll the upper deck of the ship was necessarily washed by the sea, but no water entered the turrets, the hull acting as a breakwater. The eyebolts in the wooden gun-carriages showed signs of weakness, which rendered the trials shorter than they otherwise would have been. Iron carriages are the only remedy for this, and they were applied for a year ago.

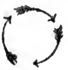
ROYAL NAVAL RESERVE.

The return of the Registrar-General of Seamen and Shipping relative to the Royal Naval Reserve, dated October 31, 1865, states that 22,449 applications had been received and 19,468 volunteers enrolled in the undermentioned ports:—Aberdeen, 629; Aberystwith, 19; Alloa, 45; Arbroath, 53; Ardrossan, 51; Arundel, 4; Ayr, 5; Banff, 28; Barnstaple, 18; Beaumaris, 19; Belfast, 67; Berwick, 46; Bideford, 31; Blyth, 85; Borrowstoness, 20; Boston, 3; Bridgewater, 210; Bridport, 28; Bristol, 991; Carnarvon, 122; Cardiff, 123; Cardigan, 28; Carlisle, 5; Colchester, 8; Cork, 196; Cowes, 3; Dartmouth, 256; Deal, 4; Douglas, 48; Dublin, 114; Dumfries, 4; Dundalk, 1; Dundee, 992; Exeter, 186; Falmouth, 87; Faversham, 31; Fleetwood, 28; Folkstone, 1; Fowey, 181; Galway, 29; Glasgow, 349; Gloucester, 1; Grangemouth, 6; Greenock, 146; Grimsby, 12; Guernsey, 2; Hartlepool, 695; Harwich, 19; Hull, 188; Inverness, 62; Ipswich, 12; Kirkwall, 3; Leith, 101; Lerwick, 216; Limerick, 26; Liverpool, 1,568; Llanelly, 33; London, 4,507; Londonderry, 2; Lowestoft, 21; Lyme, 21; Lynn, 78; Maldon, 10; Maryport, 144; Middlesborough, 9; Milford, 35; Montrose, 72; Newcastle, 264; Newhaven, 35; Newport, 6; Newry, 4; Padstow, 4; Penzance, 85; Perth, 10; Peterhead, 216; Plymouth, 396; Poole, 108; Portsmouth, 88; Preston, 1; Ramsey, 4; Ramsgate, 13; Rochester, 18; Runcorn, 9; Rye, 21; Scarborough, 35; Seaham, 502; Shields, North, 1,589; Shields, South, 450; Shoreham, 11; Sligo, 3; Southampton, 338; Stornoway, 1; Strangford, 2; Stranraer, 3; Sunderland, 1,484; Swansea, 198; Teignmouth, 25; Tralee, 2; Troon, 1; Waterford, 22; Wells, 3; Wexford, 54; Weymouth, 38; Whitby, 11; Whitehaven, 145; Wick, 1; Wisbeach, 3; Workington, 16; Woodbridge, 4; Yarmouth, 107. Of the above, 49 possess certificates of competency as Masters; 873 possess certificates of competency as Mates; 19 possess certificates of service as Masters; and 61 possess certificates of service as Mates. The force also includes 2,766 petty officers in the Merchant Service.

WEATHER.

The indications of a progressive revolving gale are a descending barometer with a regularly veering wind, or with the wind changing suddenly to the opposite point.

In the northern hemisphere storms revolve from right to left, thus :— 

In the southern hemisphere storms revolve from left to right, thus :— 

Straight lined winds blow without veering; and the barometer generally rises after they set in.

SYMBOLS TO DENOTE THE STATE OF THE WEATHER.

b Blue sky.
c Cloudy.
d Drizzling rain.
f Thick fog.
g Gloomy.
h Hail.
l Lightning.
m Misty or hazy.
o Overcast.
p Passing showers.
q Squally.
r Continuous rain.
t Thunder.
u Ugly & threatening.
v Distant objects unusually visible or brought forward.
w Wet dew.
* under any letter denotes any extraordinary degree.

The wind's force is expressed by figures:—0 calm; 1 light air; 2 light breeze; 3 gentle breeze; 4 moderate breeze; 5 fresh breeze; 6 strong breeze; 7 moderate gale; 8 fresh gale; 9 strong gale; 10 whole gale; 11 storm; 12 hurricane.—*Holland's Office and Cabin Companion.*

FRENCH SHIPPING.

A return just issued in France shows that the effective of the French Merchant Navy, sailing vessels and steamers united, on the 31st of December, 1864, was 15,184 in number, and 998,519 in tonnage. On the 31st of December, 1863, the number was 15,092, and the tonnage 985,235. The increase in the course of the year 1864 was consequently 92 vessels and 3,384 tons. The following is a detail of the number and tonnage of the vessels at the end of 1864:—

	No.	Tonnage.
Vessels of 800 tons and upwards	50	58,246
„ 700 to 800	31	22,943
„ 600 to 700	50	32,433
„ 500 to 600	119	65,196
„ 400 to 500	256	114,605
„ 300 to 400	296	104,826
„ 200 to 300	639	155,318
„ 100 to 200	1,286	181,116
„ 60 to 100	1,541	117,759
„ 30 to 60	1,586	67,742
„ 20 to 30	963	23,635
„ 10 to 20	1,591	23,113
„ below 10	6,776	31,588
	15,184	998,519

Of the above, as many as 8,596 vessels, of 41,197 tons, were employed in what the French call the "little fishery," that, namely, on the coasts of France; 6,691, and 33,877 tons, belonging to the Atlantic ports; and 1,905, and 7,630 tons, to those of the Mediterranean. The number of men occupied in the 8,596 boats was 41,197, of whom 33,877 belonged to the former ports, and 2,320 to the latter.

STEAM NAVIGATION IN RUSSIA.

Messrs. C. Mitchell and Co., of Low Walker, on the Tyne, have just received an order to build two screw-steamers of 500 tons each, for the navigation of the Caspian Sea, to which sea these vessels will sail direct from this country. The same firm are also about to build two more powerful steamships for the Russian Steam Navigation Company, and intended for their fleet on the Black Sea trading with the Crimea. They will be fitted up to carry a large number of passengers, and will be supplied with engines by Messrs. Penn and Son, of London, with all the modern improvements for the economy of fuel.

ART. XXVII.—*Launches in November.*

On 27th October, from the building yard of Mr. John Key, at Abden, Kinghorn, the iron screw-steamer *Kinghorn*, for Messrs. M'Gregor and Gibson of Leith, and destined for the Leith and Rotterdam trade.

On 2nd November, from the yard of Messrs. Backhouse and Dixon, of Middlesborough-on-Tees, the screw-steamer *Count Sponneck*, for the Anglo-Greek Steam Navigation Company. Her dimensions are as follows:—Length over all, 290 feet; breadth, 33·9 feet; depth of hold to spar deck, 26 feet 9 inches. She is 2,200 tons burthen and 1,700 tons register, and is to be fitted with direct-acting condensing engines of 300 nominal horse-power, manufactured by Messrs. T. Richardson and Sons of Hartlepool. She has three decks, and has cabin accommodation for about 40 first-class passengers.

There has just been launched from the yard of Messrs. Bowdler and Chaffer, Seacombe, an iron screw collier named the *Agnes Jack*. She is almost a counterpart to the screw collier *Jane Beacon*, which was launched from this yard a few months ago, the only difference being that the *Agnes Jack* is 10 feet longer.

On 4th November, from the building yard of the Millwall Iron Works and Shipbuilding Company, the iron-clad cupola frigate *Affondatore*. Her principal dimensions are as follows:—Length, 298 feet; breadth, 40 feet; depth, 18 feet 4 inches; builder's tonnage, 2,306 tons, and 700 nominal horse-power. She is fitted with two turrets on Captain Coles's principle.

On 4th November, from the yard of Messrs. Hart and Sinnot, Liverpool, the iron screw-steamer *Augustine*, for the West India and Pacific Steamship Company.

On 4th November, from the yard of Messrs. Jones, Quiggin, and Co., Liverpool, an iron screw-steamer of about 1,000 tons, for Messrs. Reynolds, Mann, and Co., and intended to trade to the East Indies.

On the 2nd instant Messrs. Thomas Wingate and Co. launched from their building yard at Whiteinch, on the Clyde, a screw-steamer of 500 tons, and 80-horse power, for the Spanish trade, built to the order of Messrs. W. Cruickshank and Co., Glasgow. On leaving the ways she was named *Matilde*, by Senora Josefa Antonia de Oginaza Sa de Nonandi, of Bilbao. Shortly after the launch steam was got up and the engines started.

On 4th November, from the yard of the Thames Iron Works and Shipbuilding Company, Blackwall, the iron-cased frigate *Victoria*, 30 guns, 1,000-horse power, and 4,862 tons, for the Queen of Spain. Her length between perpendiculars is 316 feet; her keel for tonnage, 282 feet; breadth for tonnage, 57 feet; and depth of hold, 38 feet.

On 18th November, from her Majesty's Dockyard, Deptford, the screw steam-frigate *Endymion*. She is one of the old class of frigates, to carry 36 guns. She was laid down on the 20th October, 1860. The principal dimensions are as follows:—Length between perpendiculars, 240 feet; ditto of keel for tonnage, 207 feet $11\frac{5}{8}$ inches; breadth extreme, 47 feet 10 inches; depth of hold, 17 feet 3 inches; tonnage, 2,478 tons; horse-power, nominal, 500. Her armament will consist of four 100-pounder Armstrong rifled muzzle-loading guns, and 14 8-inch guns on the main deck, and 9 110lb. breech-loaders on the upper deck.

On 18th November, from the yard of Mr. Charles Lungley, Deptford, the iron-cased gunboat *Vixen*, for her Majesty's Navy. Her dimensions are—Length, 160 feet; breadth, $32\frac{1}{2}$ feet; depth, 13 feet 7 inches; her builder's measurement is 740 tons; she is built on the combination principle, and her armour-plates, which are 4½ inches thick, are sheathed with wood. She is propelled by twin screws, with engines of 160 nominal horse-power; and the armament consists of two 300-pounder howitzer shunt guns, and two 24-pounder howitzers.

From the iron shipbuilding yard of Messrs. Pearse and Lockwood, Stockton, the screw-steamer *James Shaw*, 160 feet long, 25 feet beam, 15 feet hold, 550 tons builder's measurement; engines by Messrs. Fossick, Blair, and Co., of 70 nominal horse-power, with all the latest improvements. She is fitted up with steam winches, and is for the Tees and Thames Company.

On 18th November, an iron ship of 1,000 tons register, named the *Andaman*, was launched from the building yard of Messrs. John Reed and Co., Port Glasgow, for the British and Eastern Shipping Company.

At Havre, on 20th November, a steamer in the form of a cigar, built by Messrs. Nillus and Sons, was launched. It is constructed on the plans of Mr. Winans, of Philadelphia, is 22 metres long, and 2 metres 75 centimetres in diameter in the middle (the metre is about 3 feet 3¼ inches). It has eight screws, of which six are entirely under water and two partially so, and is of about 25-horse power. The interior is divided into compartments. The vessel has been constructed by way of experiment.

From Pembroke Dockyard, by John Fincham, Esq., master shipbuilder, her Majesty's ship *Vestal*. She is intended as a despatch vessel, and has a projecting prow from beneath the water-line. Her dimensions are—length between perpendiculars, 187 feet; length of keel for tonnage, 158 feet; breadth extreme, 36 feet;

breadth for tonnage, 35 feet; depth in hold, 19 feet; burthen in tons, 1,081; armament, four heavy guns; horse-power, 300.

On the 18th November, from Palmer's Shipbuilding and Iron Company's Yard, Jarrow, three vessels were launched—viz., the *Margam Abbey*, 182 feet between perpendiculars, 26 feet beam, 15 feet depth of hold, 598 tons builder's measurement. This vessel is intended to run between Milford Haven and Waterford. One vessel, of the following dimensions:—Length between perpendiculars, 255 feet; extreme breadth of beam, 32 feet; depth of hold, 22 feet; tonnage (builder's measurement) 1,284 tons; belonging to Messrs. Robinson and Co., London, for the South American trade. Also a collier, for the same firm, of the following dimensions:—Length between perpendiculars, 210 feet; breadth of beam, 28 feet; depth of hold, 17 feet, 6 inches; (builder's measurement) 806 tons.

On the 21st November, from the yard of Messrs W. Denny and Brothers, the iron screw-steamer *A. Lopez*, of 2,000 tons register, and 400-horse power nominal. This vessel is intended for the Cadiz and Havana mail service, carried on by Messrs. A. Lopez and Co.

Art. XXVII.—*Trial Trips in November.*

The iron-cased screw-steamship *Lord Clyde*, 24, was taken outside Plymouth Sound on Saturday, 11th November, to make a trial of her engines, under the inspection of Captain Edmondstone, C.B. Mr. Steel, Assistant-Engineer from Keyham Steam-yard; Mr. Dinnen, Inspector of Machinery Afloat; and Mr. Saunders, Second Master Shipwright, were present on the part of the Admiralty. Mr. Ravenhill represented the manufacturers of the engines. In consequence of bad weather she was only able to make two runs at the measured mile, but these, considering her peculiar construction, were very satisfactory. The *Lord Clyde* was built at Pembroke on the lines of Mr. Reed, Chief Constructor for the Navy. She is 280 feet long, 58 feet 9 inches broad, and has a depth of hold of 20 feet 9 inches, her burthen in 4,067 tons. Her engines are fitted with cylinders of very large diameter for the purpose of using the steam expansively; also with surface condensers. She has tubular boilers (with superheaters), having brass tubes 2½ inches outside diameter, and containing an aggregate heating surface of 19,000 square feet, with a great surface of 700 square feet. There are nine boilers, arranged in two groups—one of four boilers, the other of five—each group having a chimney 7 feet 1 inch in diameter. The engines are capable of exerting an indicated power of 6,000 horses. They are a pair of direct-acting horizontal engines with double piston rods, the cylinders are 116 inches diameter, length of stroke 4 feet. Each cylinder weighs upwards of 30 tons, and the crank shaft weighs 25 tons. The draught of water was 22 feet 4 inches forward, and 24 feet 10 inches aft. The vacuum in the condensers 27 inches, aft 28 inches. Speed first run, 4 min. 26 sec.; second, 4 min. 26 sec., equal to 13·533 knots per hour. The speed of the screw was 12·825, showing a negative slip of ·708, or nearly three-quarters of a knot. Revolutions first run, 55½ per minute; second, 56;

indicated horse-power 6,110; propeller, four-bladed, 23 feet diameter, pitch 22 feet 6 inches. Wind north-east, force 1 to 2. Sea smooth.

The *Bristol*, 39, steam-frigate, 3,027 tons, 600-horse power, Captain Leveson E. H. Somerset, which has been fitting in Sheerness Dockyard for service on the West Coast of Africa, as flagship of Commodore T. P. Hornby, was taken on Tuesday morning, the 8th of November, to the measured line off Maplin Sands for the final trial of her engines previous to leaving for her destination. She made six runs on the measured mile, with the following results:—First run, 7 min. 3 sec.; revolutions of engines, 57·25; speed due to time, 8·511. Second run, 4 min. 41 sec.; revolutions of engines, 58; speed due to time, 12·811. Third run, 7 min. 13 sec.; revolutions of engines, 56; speed due to time, 8·314. Fourth run, 4 min. 43 sec.; revolutions of engines, 58; speed due to time, 12·721. Fifth run, 6 min. 58 sec.; revolutions of engines, 56; speed due to time, 12·632. Her true mean speed was 10·596. Two runs were also made at half-boiler power, giving a true mean speed of 8·054. The draught of water forward was 21 feet 2 inches; aft, 24 feet 1 inch. The load on the safety-valve was 20lb. The state of the sea was rough, and the wind was blowing from N.N.E. with a force of 5 to 6. The vessel was fully rigged, having all her stores on board and 404 tons of coals. The engine and boilers performed their respective duties very satisfactorily, and had the weather been favourable a greater speed would have been obtained.

On a subsequent official and final trial at the measured mile in Stokes Bay, on 16th November, the draught of water, after having stowed her anchor and made all ready for running the mile, was 20 feet 11 inches forward, and 23 feet 11 inches aft, the wind being at a force of from 3 to 4. It was from S.S.E., and there was a slight movement of water over the vessel's course, but not enough to affect her speed in the slightest degree. Under these conditions ten runs were made, six with full and four with half-boiler power, with the following results:—Full boiler power, six runs, 12·371, 10·286, 12·587, 9·524, 13·043, 9·549 knots; the mean of the six runs giving the ship a true measured-mile speed of 11·272 knots. The mean vacuum was 26½ inches, with the safety-valve loaded at 20lb., and the revolutions of the engines were, *maximum* 60, *minimum* 58. The four runs with half-boiler power gave 11·726, 7·214, 11·077, and 8·163 knots; the ship's mean speed being 9·346 knots. In comparing these results with the recent Maplin Sand trial, it will be found that on this occasion the ship gained an additional speed of 0·676 knot with full boiler power, and 1·292 knot with half boiler power, a mean excess of 2 being also gained in the revolutions of the engines.—*Times.*

The dimensions of the *Bristol* are—length between perpendiculars, 250 feet; extreme breadth, 52 feet; and when tried in the Thames in 1860 before being masted and rigged, she obtained a mean speed of 12·54 knots, at a draught of water of 17 feet 4 inches forward and 20 feet 3 inches aft; her engines indicating on that occasion 2,550-horse power.

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The Turkish paddle-wheel yacht *Fuad* went down the river on her official trial on Monday, 21st, and made the prescribed run at the Lower Hope. She was built by the Millwall Company, under the direction of Mr. Charles Lungley, and is of iron. Her principal dimensions are—length between perpendiculars, 258 feet; extreme breadth, 29 feet 6 inches; depth of hold, 18 feet; and 1,076 tons burden. Her rate of speed was registered at 16¼ knots per hour. The engines, of 300-horse power nominal, are on the oscillating principle, with feathering paddle-wheels, made by Messrs. Ravenhill, Hodgson, and Co. During the trial, which was highly successful, they made 41 revolutions per minute.

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On the morning of the 27th October the *Ravensburg*, built by Messrs. Dudgeon for the Great Eastern Railway Company, and intended to ply between Harwich and Gothenburg, made a very successful trial trip down the river. The following are the dimensions of the *Ravensburg*:—She is 256 feet over all; her beam is 27 feet, and her depth 13 feet 10 inches; she is 860 tons burthen, and has good berth and saloon accommodation for 120 passengers, besides being able to carry 250 beasts, 600 sheep, and 80 tons of general cargo. She has oscillating engines of 220-horse power; the cylinder is 54 inches in diameter, with a stroke of 4 feet 6 inches. There are two boilers with five furnaces in each, having a total fire-bar surface of 204 square feet, with annular superheaters and link motion. The *Ravensburg* passed the measured mile, both going and returning, at a pace which promises 13 or 14 knots an hour from her.

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The double-turreted screw corvettes *Wyvern*, Capt. Burgoyne, V.C., and *Scorpion*, Captain Commerell, V.C., have both arrived at Spithead from Portland on the conclusion of their experimental Channel cruising. Both vessels having left Spithead, their orders were to make Portland Roads their anchorage ground each night, and, according to directions, to steam or sail out to the southward of Portland Bill, and try their powers. In accordance with these orders, the *Wyvern* and *Scorpion* have been tested fully in all weathers possible in the Channel, under steam alone, under canvas alone, and under steam and canvas conjointly, the waist bulwarks of each ship being both lowered and raised on each trial. Under steam alone both vessels were taken into the Race of Portland during the prevalence of a very stiff gale, and were laid for some time broadside on to the seas and the tideway. Under these trying circumstances, the *Wyvern* rolled 24 degrees each way, and the *Scorpion* 14 degrees. Under canvas alone, and also under steam and canvas combined, the *Scorpion* rolled in the same proportionally less degree than the *Wyvern*, and under all circumstances, whether under steam or sail separately, or both combined, the *Scorpion* maintained a speed of three-quarters of a knot per hour in excess of the *Wyvern's* rate of going.

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The Turkish yacht *Mahmoud* went down the river on a trial of her speed. She is an ironclad, with 5½-inch plates, and is upwards of 4,000 tons burthen. She is engined by Messrs. Ravenhill, Hodgson, and Company. The ship was built by the Thames Iron Shipbuilding and Dry-dock Company (Limited). She was tried and commenced her official run at the Maplin on the 15th inst., and afterwards proceeded on her voyage to Constantinople, calling at Plymouth. The Turkish officer in charge was Captain Hassan Bey. The speed of the ship was over 12 knots per hour, the engines making 55 revolutions per minute. The ship was launched about a year ago, and has not been docked since, consequently her bottom is exceedingly foul. She and the Turkish frigate *Abdul Aziz*, Captain Hussein Bey, from Greenock, arrived at Plymouth on Saturday. While in the Sound they will, it is said, embark 1,600 tons of coal, and will not, therefore, be under the necessity of taking in any fuel between Plymouth and their port of destination —Constantinople.

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The twin screw-steamer *Honfleur*, built for the passenger service between Littlehampton on the south coast and Honfleur in France, made her trial trip on 25th November. She was designed, built, and engined by the Millwall Iron Works Company. On arriving at Long Reach, the wind blowing strongly, two runs were made at the measured mile, the first with the tide in 3 min. 50 sec., and the second against the tide in 6 min., giving in the first case a speed of 15·65 knots, and in the second 10, showing a mean speed of 12·83 knots. After the completion of the speed trials the steering experiments were commenced. It was found that with the vessel at full speed, by putting the helm over and reversing one screw, she was turned through the half circle in 1 min 50·sec., and through the full circle in 3 min. 40 sec.—*Times.*

Art. XXIX.—*List of Patents, from September 18th to October 14th, 1865.*

2493 D. Spink. Propelling. Sept. 28.
2512. E. Lindner. Breech-loading Guns, Projectiles, and Cartridges. Sept. 30.
2563. R. W. Fraser. Propelling and Steering Ships. Oct. 5.
2576. W. D. Grimshaw. Capstans. Oct. 6.
2589. T. M. Gisborne. Cleansing the Bottoms of Ships. Oct. 7.
2601. W. Clark. Propelling Vessels. Oct. 9.
2635. G. and A. Deslandes. Windlasses. Oct. 12.
2641. G. Rosselet. Propelling Ships. Oct. 13.
2653. W. J. C. McMillan. Cleansing the Bottoms of Ships. Oct. 14.

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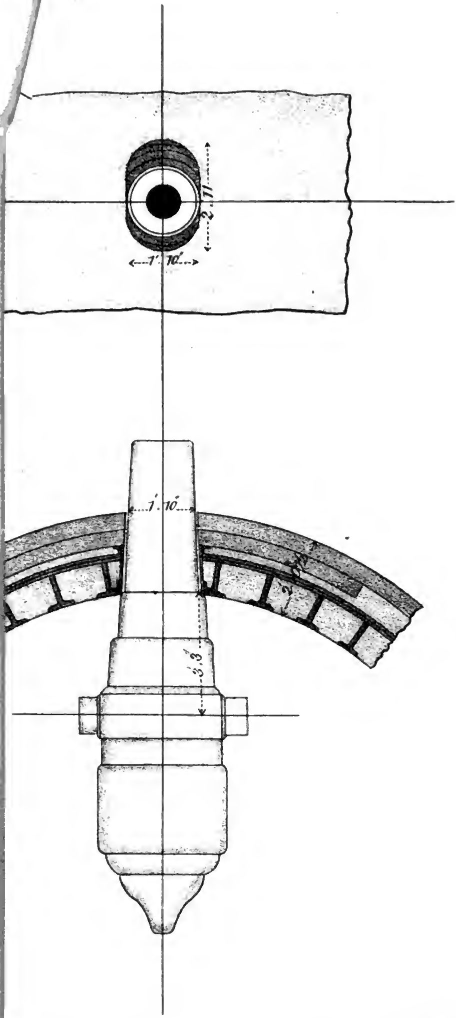
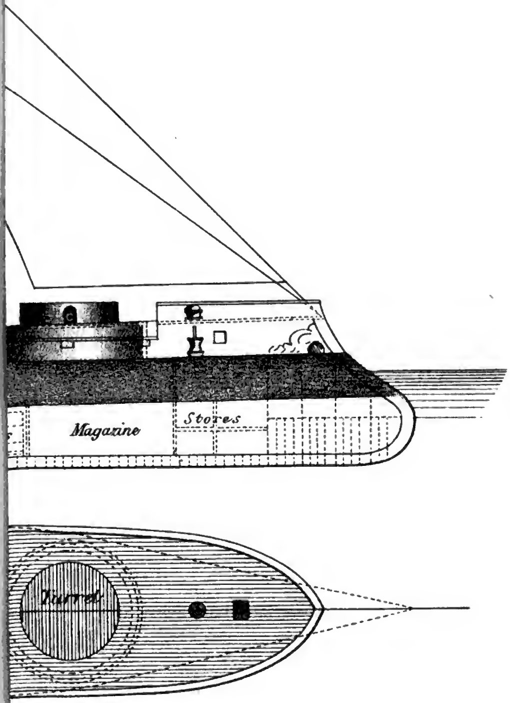
P^{or} Gun



Part 1

Plate 5.

Shipbuilding Company.



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